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Treated Water Demand and the Economics of Regionalization

Volume 1
The Residential Demand for Treated Water

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16. ABSTRACT

This two-volume report examines the present and future demands and costs for residential water in view of the new requirements for water quality standards under the Safe Drinking Water Act of 1974 (PL92-523). Volume I (this volume) investigates the determinants of residential water demand (including water price, family income, and appliance ownership) and develops a methodology by which utilities can determine future customer demand. A data base has been developed, and results of the analysis are given. These data can be used to test many hypotheses other than those examined in this study, and then could be a valuable tool for further research into the household demand for water.

One of the most significant products of this research is the development of a information collection format that can be used by a water utility to collect data on household water use.

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Volume 1. The Residential Demand For Treated Water

by

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

This report presents a data base and methodology for estimating the determinants of residential demands for treated water.

Suggestions are also made regarding methodologies useful for future research into the nature of water system costs by drawing upon the literature on the electric power industry.

Francis T. Mayo, Director
Municipal Environmental
Research Laboratory

ABSTRACT

This two-volume report examines the present and future demands and costs for residential water in view of the new requirements for water quality standards under the Safe Drinking Water Act of 1974 (PL 92-523). Volume 1 investigates the determinants of residential water demand (including water price, family income, and appliance ownership) and develops a methodology by which utilities can determine future customer demand. A data base has been developed, and results of the analysis are given. These data can be used to test many hypotheses other than those examined in this study, and they could be a valuable tool for further research into the household demand for water. Methods are discussed sufficiently to provide a point of departure for water utilities that may wish to analyze their own demand.

Volume 2 investigates consolidation in the electric power supply industry as an example of a possible method of offsetting the increased costs of water treatment that will be incurred under the new Federal regulations. The structure of the power industry is examined and the history, advantages, and cost benefits of coordination are evaluated. Several alternatives to the present system are considered, including consolidation of existing systems, encouragement of competitive markets, and public ownership of generation and transmission facilities.

This report was submitted in fulfillment of Contract No. R805617-01-1 by The University of Alabama under the sponsorship of the U.S. Environmental Protection Agency. The report covers the period 4-1-78 to 12-31-79 and work was completed as of 12-31-79.

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SECTION 1

INTRODUCTION

The object of this two-volume study is to examine the determinants of residential water demand, to develop a method for determining future customer demand, and to investigate the possible benefits of regional consolidation as a method of offsetting the increased costs that will be incurred with the new Federal regulations under the Safe Drinking Water Act of 1974 (PL 92-523).

This first volume accomplishes two main tasks. First, it examines the determinants of residential water demand with regard to water price, family income, and the number of water-using appliances in the home. Second, Volume 1 develops a methodology by which utilities can determine future customer demand.

To accomplish the first task of examining residential demand, a data base was developed and analyzed. These data can be used to test many hypotheses in addition to those examined in this study, and they could be a valuable tool for further research into the household demand for water.

A detailed description of the data base is given in Section 3, and the methods are discussed sufficiently to provide a point of departure for water utilities that may wish to analyze their own demand.

The estimation of price and income effects on water consumption is discussed in Section 4 along with a consideration of many of the technical problems associated with estimating demand equations when price to the consumer is determined by a block rate structure. Aside from the conclusion that the price elasticity of water is very low, the chapter will be of primary interest to those concerned with the econometrics of the study. Section 5 discusses the relationship of appliance ownership to the demand for water and the usefulness of descriptive statistics in analyzing water demand. The chapter should be of particular interest to those concerned with pricing and conservation policy and forecasting.

SECTION 2

CONCLUSIONS

The data base in this study is unusual when compared to others used to estimate residential water demand. It provides an unusually sound basis for the study of price and income effects when the cost of the goods to the consumer is determined by a block rate structure. Even this data base has certain limitations, however, including the implicit assumption that individuals in different cities have the same reactions to price changes. The ideal study would impose different rate structures on individuals in the same location and then determine the effects of these different rate structures.

These data are useful for presenting a general understanding of price elasticity relationships. But to make specific policy decisions, a similar study should be conducted by the affected utility. The techniques developed as a result of this study indicate that such a data collection effort is feasible at reasonable cost.

The primary conclusions drawn from the data base analysis are as follows:

1. The number of persons in the home and family income are the most important determinants of water consumption.

2. Price affects consumption, but much less than has been indicated in most previous studies. The findings of this study indicate a price elasticity of -0.2 as opposed to estimates of approximately -0.6 in recent studies. The policy implications of this are far reaching, since a utility that needs a 5 percent increase in revenue would have to raise rates only 6.35 percent if price elasticity is 0.2, and 16.67 percent if price elasticity is 0.6. Thus environmental regulations that increase revenue requirements may not create as many problems for the utilities as had been expected under previous elasticity estimates.

3. The presence of various water-using appliances affects the use of water, but the presence of household appliances is generally a reflection of income, and therefore information on appliances may be redundant if accurate income data are available.

4. The presence of a lawn sprinkler provides little indication of water use for irrigation. The percent of customers irrigating (which averages 20 percent over all income groups) increases with income; but heavy waterers are found scattered throughout the moderate-to-high income levels, and they are in the minority at all income levels.

5. The use of water for lawn irrigation is an important source of residential water demand during the summer months. The price elasticity of water used for irrigation is not radically different from that for other uses.

6. Completely eliminating lawn irrigation cannot greatly curtail the need for new water supplies, since irrigation water accounts for only about 3.5 percent of total use. Controlling lawn irrigation use is useful in solving peak load problems, however.

7. Significant water conservation is unlikely to be achieved through the use of rational rate increases. Future reductions in water demand will more than likely come from technological changes in the household water-consuming appliances. Some of these changes (for example, the use of bottle dames in toilet tanks) can be implemented quickly with the shock effect of high-penalty water rates. Other techniques (such as building codes requiring water-efficient appliances) would take years to produce a meaningful change in the average use per household.

8. If the peak load is 10 to 20 percent above normal levels, there is no economic justification for declining block rate structures that encourage (or fail to discourage) the increased demands of irrigators. A declining block rate structure is socially and economically justifiable up to a usage level representing the average monthly use for a large family. For above-average use, or for higher summer use within a household, however, the most justifiable structure might be an increasing block rate structure.

9. An increasing block rate structure may be feasible only in systems with computerized billing systems, and it would induce only limited conservation with relatively high, widely publicized rates.* The primary advantage would be that the revenue would be collected from those primarily responsible for the peak load.

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*A fair billing system for conservation would require that the number of household occupants be considered in determining the point at which the increasing block rate would take effect and/or when a given customer consumed greater than his usual average.

SECTION 3

SOURCES AND ORGANIZATION OF DATA

The data used in the study were obtained from several sources and organized into two data sets. This chapter describes the data sets and their sources, quality, and limitations. A section on survey methods and applications also provides suggestions for use by other utilities who may want to forecast demand. Copies of questionnaires (which may be useful in future studies) are reproduced in the appendices.

HOUSEHOLD INFORMATION AND SURVEYS USED

The two data sets used were based on separate surveys of utility customers. The first and larger sample of more than 700 is referred to as the statewide set, and it serves as the basis for the elasticity estimates developed in Section 4. A second, smaller sample (188) was drawn from a single water utility and is referred to as the local sample. The local set is used primarily as a supplement to the statewide set, first in defining price (Section 4), and later in the analysis of detailed characteristics of water consumption (Section 5).

STATEWIDE DATA SET

The first survey was conducted by a utility serving a large part of the State of Alabama in early 1977 as part of a (usually) biannual series. (The exact data source must remain confidential.) Information on household occupants, income, appliance ownership, and housing characteristics was obtained from interviews conducted in the customers' homes. The authors were permitted to add some key water questions to the survey in anticipation of this study, and to participate in field testing and other aspects of the survey. Overall emphasis was on determining appliance saturation and conservation practices of electric utility customers. The same type of domographic and appliance information is needed for a water survey. Thus various utilities interested in making such surveys should consider conducting them as a joint effort.

The statewide survey included 3,000 interviews with customers from the service area. Interviewers were chosen from 3,000 pairs of names randomly drawn from all customers. Each pair consisted of two consecutive customers in a meter-reading route, and a prime and an alternate was designated for each. Alternates were interviewed only if the prime could not be contacted after several attempts over a period of time.

More than 60 water utilities serving the geographical area of the original interviews participated in an effort that successfully matched more than 1,200 interviewees with the names and addresses of water customers. The largest loss stemmed from the failure of one large metropolitan area to participate (because of legal advice) and the inability or unwillingness of several smaller water systems to participate. In addition no water records were available for many interviewers because water is often furnished in rental units and the service area of the interviewing utility included areas with no water service. The data set was further reduced to 1,008 records by eliminating the records from systems that were not on a monthly billing cycle. The remaining records were compiled by statistical distributions and compared with similar statistics from the original 3,000 records. The comparison indicated that the sample reduction was essentially random. For example, the average number of occupants is 3.0 in the recorded sample versus 2.9 in the full set; average family income is $12,500 versus $11,500, etc. The direction of change is consistent with the loss of samples that occurred because of furnished water (about half of the apartments and mobile homes) and because of rural residents without water service. Thus the sample of 1,008 seems to represent about the same population as does the sample of 3,000. The sample of 1,008 was used in a number of descriptive statistical tabulations and serves as the basis for part of the analysis in Section 5. The regression analysis in Section 4 is based on a sample size of 773. This further reduction was necessary so that identical billing months could be used for samples and so that samples with large leaks or other questionable content could be rejected.

Regressions were also run on subsamples from three cities (i.e., three separate water systems). One contained 153 samples, another had 97 samples, and the last had 55. These subsets were used for a limited comparison of variations in water consumption patterns among the water systems.

LOCAL DATA SET

The second survey was conducted under the direction of the authors during the summer of 1978 as part of a continuing study of residential energy demand and as a means of obtaining specific information on water use not included in the statewide survey. Utility customers drawn from a sample in one city were interviewed by telephone. A major objective was to determine how well customers understood the price under block rate structures and which component of price influenced their consumption. The problem of the appropriate price specification is common to all utility demand studies. A second purpose of the local survey was to add questions about the ownership and use of water sprinklers, the frequency of car washing, and the presence of swimming pools, water-cooled air conditioners, or other large water-using appliances. Finally, the survey was used to test some innovations in interview techniques.

A random sample of 250 customers was drawn for the local data set. Because of several changes in the questionnaire (primarily in the effort to pinpoint sprinkler use) and a number of unsuccessful attempts to contact some of the samples drawn, only 188 usable samples were obtained. The customers

interviewed are slightly biased toward older heads-of-households and higher incomes.

USE OF SURVEYS AND SURVEY METHODS

Gas and electric utilities have a long history of surveying the appliance ownership of their customer. The earliest surveys of the utility providing the statewide data set for this study were concerned with determining saturation rates for ranges and water heaters. The major question was whether these appliances had been accepted rather than the type of fuel used, thereby establishing whether there was a market for selling such appliances. Later, more appliances were added to the surveys, and the emphasis shifted to market shares and competitive positions, as virtually all customers owned ranges and water heaters of some type. The saturation of appliances is also of increasing importance to gas and electric utilities in forecasting both peak system demand and long-range sales. These data have also been used, with limited success, in estimating bills during a month when the meter was not read and in experimentation with monthly billings and quarterly meter readings.

We are not aware of surveys by water utilities similar to those by gas and electric utilities in the United States, and only Batchelor [1975] (in England) has made use of such surveys in readily available water research literature. Our speculation is that water system management would have received only marginal benefits from such data in the past: however, as trends toward higher cost and increasing scarcity continue, relatively simple survey techniques and analyses will be of increasing value in pricing and other measures to alleviate the peak load problem (if any) and encourage conservation.

For most managerial questions, including rather simple evaluations of elasticities within a particular water system, we believe that a simple data set could be collected by much less elaborate survey methods than used here. However, the usefulness of survey data could be greatly enhanced by (1) tracking a sample of customers over time for an evaluation of water use changes for those customers remaining at the same place, (2) following customers in the sample that move elsewhere in the system, and (3) tracking the water use in the original housing unit as occupants change. More sophisticated studies of elasticities and how they may differ with location, density, or other characteristics would also benefit from survey designs incorporating the longitudinal observations suggested above. Thus the inclusion of questionnaires in the appendices and the following description of key survey techniques are offered only as suggestions, not as a package for replication.

The differences in interview methods should be of interest to those planning surveys. The statewide survey interviews were conducted in the customers' homes, and emphasis was placed on the accurate recording of exact responses. Only questions with definitive and objective answers were used in order to avoid bias or error by the interviewer. In some questions, however, the interviewer was allowed to help with factual questions such as the number of square feet of heated space. In the local survey interview, emphasis was placed on the skill of the interviewer in avoiding bias or error in a

tradeoff for additional objectives. The first objective was to cut the average time per interview by asking open-ended questions, such as "how much water do you use outside the house?" Most responses, as anticipated, included the details sought with minimum need for follow-up questions. A second objective was to obtain the interviewee's perception of prices and a description of how key appliances were used. To obtain such information from questions in a simple yes or not format would have required much longer, with no assurance of greater accuracy.

The results with open-ended questions were highly satisfactory in more respects than the closed questions. After a little experience, the interviewers found that most information sought could be quickly obtained. They also suspected (and the results confirmed) that the attempt to quantify sprinkling in terms of frequency and intensity was unsuccessful. Some respondents who claimed to water lawns "frequently" used considerably less water than those who thought they sprinkled just enough to keep the grass from dying--primarily a difference in viewpoint between moderate- and high-income customers. (Similar attempts to obtain information on the intensity and frequency of use of energy-using appliances were much more successful.)

The statewide and local interviews were also different in emphasis. Of major concern in the statewide survey was obtaining results representative of the population, and a large and random sample was important. The local survey interview was designed to fill gaps in statewide data sets and to develop estimated ranges of water amounts used by irrigators as opposed to the total or average amount of water used for irrigation.* For such questions, accuracy in a limited and non-random number of observations is more important than the usual considerations to avoid bias.

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*Data on lawn watering practices were used to develop a technique for identifying customers with high irrigation demand in the primary data set. The technique is further discussed in Section 5.

SECTION 4

EFFECTS OF PRICE AND INCOME ON WATER DEMAND

Interest in the price elasticity of water is associated with policy measures to encourage conservation and with forecasts of system loads. Earlier studies have focused on the amount of conservation caused by metering, and they have stimulated interest in estimating the elasticity of water demand (Howe and Lineweaver, 1967; Clark and Goddard, 1977; Batchelor, 1975). Initially, conservation appeared to be synonymous with restricting the demand for sprinkling, but later studies suggest possible reductions of in-house usage as great as 30 percent (Howe and Vaughn, 1972). More recently, a greater public interest in both price and non-price control measures has been created by environmental objections to reservoirs, the high cost of upgrading water and sewer treatment facilities, and forecasts of critical water problems in many areas (Consumer Reports, 1978).

Published estimates of price elasticities range from zero to above unity, and there is little evidence of consensus as to the actual magnitude (see Goddard et al. (1977) for a detailed literature review on residential water demand). In spite of evidence that the elasticities in humid areas are probably difference from those in arid areas, and that different usage patterns may exist in urban and rural areas or in cities of different sizes, it is unlikely that these differences could account for the wide range in elasticity estimates. Limited experimentation with pricing to induce conservation suggests that the demand for water is quite inelastic, however. In one case cited by Consumer Reports (1978), an affluent suburban water system accomplished a 65 percent temporary reduction and (apparently) a 45 percent permanent reduction in residential water use, partially by prohibiting outside use, but mostly through a temporary inverted rate structure. Rates were doubled for consumption up to a targeted high conservation quota per household; they were increased eightfold for consumption up to twice the quota; and they were raised fortyfold beyond that level.

We contend that the higher estimates of price elasticity stem from misspecification of price variables. After a review of the controversy, we tested this hypothesis by recreating the errors found in previous studies and comparing the results with estimates from more plausible price specifications. The findings explain the wide range of estimates previously reported and point out the type of improvement needed in future studies. Tentative estimates of the water demand elasticities in our study area are then evaluated on the basis of suitability for pricing policy and forecasting.

In this section, the concept used for estimating elasticity is related to the empirical calculations. Examples are generally drawn from the data, analyses, and definitions used in subsequent sections. In addition, key definitions are given for ex post and ex ante prices as applied to the average and marginal prices used in the study, and two additional prices are introduced that have been developed in the theoretical literature but not extensively in empirical work--the intramarginal price and the lum sum. These four price variables are tested and compared in various combinations is various combinations in several estimating equations. The best combination of price variables and estimating equation is used to develop elasticity estimates for the study. This section also illustrates some policy applications of demand analysis.

METHODOLOGY FOR ESTIMATING PRICE ELASTICITY

This subsection outlines the concept of elasticity and the generally accepted methodology for estimating it. First, it is essential to understand two basic types of pricing--ex ante and ex post. When a conventional good is priced by the seller ex ante, the price per unit is given before the amount purchased is decided. There are no discounts for large purchases or penalties for small purchases. Ex post, or after the fact, pricing is used to determine water bills under block rate schedules.

The following discussion of estimating conventional ex ante elasticity identifies several alternative methods of price specification that have been used in estimating the price elasticity of utility services. The comparison shows how the ex post block rate pricing system used by utilities has created unique problems in the proper specification of price.

Concept and Calculations

The law of demand states that the price of a good determines the quantity taken, all else equal. Price elasticity is a measure of the inverse relationship between price and quantity hypothesized by the law of demand. Or, stated more simply, elasticity is a measure of the relative influence of price on the quantity taken. Conceptually:

$$e = \frac{\text{percent change in quantity taken}}{\text{percent change in price}}$$

The standard method of calculating price elasticity is illustrated in Figure 1(a), in which a drug chain has set up a controlled experiment to determine the price elasticity for their brand of toothpaste. In one store, they have priced Brand A at $1 per tube and find that 100 boxes of 20 tubes each are sold per month. In a second store, located in another shopping center with essentially identical characteristics (customer traffic, neighborhood income, etc.) sales of 110 boxes are obtained at the lower price of $0.90. The demand curve illustrated is fit to the data and extrapolated.

The conceptual formula must be modified to obtain logically consistent results. The can be seen from a literal interpretation of the conceptual

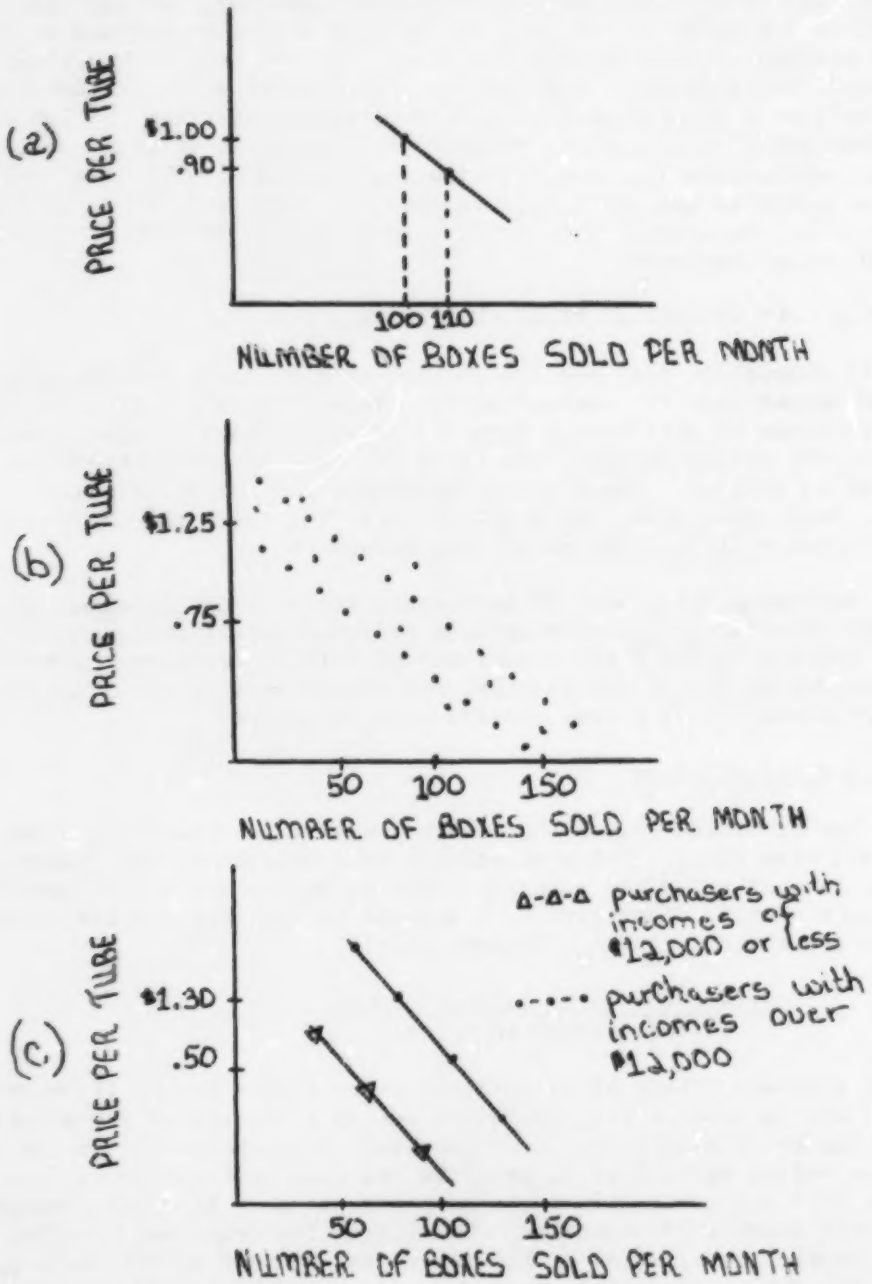

Figure 1. Demand for Brand A toothpaste.

formula. Assuming a drop in the price to $0.90, elasticity would be:

$$e = \frac{+10/100}{-.10/1.00} = \frac{10\%}{-10\%} = -1.0$$

or, if we assume a price increase:

$$e = \frac{-10/110}{+.10/.90} = \frac{-9\%}{11\%} = -0.8$$

Actual estimates are obtained by the empirical definition:

$$e = \frac{\text{change in quantity/average of the initial and final quantities}}{\text{change in price/average of the initial and final price}}$$

$$= \frac{10/105}{.10/.95} = \frac{9.5\%}{10.5\%} = 0.9$$

It is understood that a price elasticity coefficient is negative, so elasticities are sometimes referred to without making the sign explicit. The use of percentages insures that the calculations would be identical if price had been stated in cents rather than dollars, or if quantity had been stated in tubes rather than boxes.

The nature of an elasticity estimate is further clarified by assuming that a third store in the controlled experiment recorded sales of 90 boxes at a price of $1.10. If elasticity is calculated for the arc of the demand curve between $1 and $1.10 (as opposed to the arc between $1 and $0.90 as in the paragraph above):

$$e = \frac{10/95}{.10/1.05} = 1.1$$

The elasticity may differ depending on which range of the demand curve is chosen in making the calculation in this example.

A major point to be made by the above examples is that an elasticity estimate is only an approximation of the price-quantity relationship. In general use, most economists would refer to either the 0.9 or the 1.1 estimate as "about unitary," meaning that the change in sales to be expected from a change in price would be about in proportion to the price change. Similarly, elasticities of 0.4 or 0.5 would indicate that the product was relatively price inelastic, or that sales were not very responsive to the price.

Since controlled experiments are rare, Figure 1(b) offers a more realistic picture of a typical data base used in elasticity estimates. Here, price-quantity observations for Brand A during a given time period are plotted for several outlets of the hypothetical chain of drugstores. The scatter occurs partly because the outlets of the chain are in neighborhoods of various income levels and different population densities. To estimate the price elasticity, the independent variable, sales, is explained by price (P),

income (I), population (POP), and any other relevant factors in a multiple regression demand equation:

$$Q = b_1 + b_2 P + b_3 I + b_4 POP + \ldots$$

The coefficient b_2 is used to obtain an estimate of the price elasticity. Similarly, b_3 provides the estimate needed to calculate an income elasticity. Income elasticity is a measure of the relative influence of income on the quantity taken; the calculation is similar to those illustrated above, except that income is substituted for price. The population variable is included, along with other factors, to hold all else equal.

The concept of quantity being partially determined by price and partially determined by income is further illustrated in Figure 1(c). The demand curve to the left represents purchases in response to price differential by purchasers with incomes up to $12,000 per year. On the right, the demand curve represents the influence of price for purchasers with incomes over $12,000 per year. These estimates would be obtained by splitting the data deck at the approximate median income and explaining the quantity taken in each data subset. As illustrated, the higher-income groups purchase more at any given price, and their demand is less price elastic than the demand of the lower income groups.

Linear and Curvalinear Shapes of the Demand Curve

Instead of hypothesizing a straight-line relationship between quantity taken and the determinant variables, as in Figure 1, a curvalinear relationship could be used in other specifications of the estimating equation. A common alternative to the specification above is to specify all variables in natural logarithms. Log-linear estimates of the demand equation have the special characteristic of explaining the percentage change in quantity taken by a percentage change in price or income. The coefficients thus become direct estimates of the elasticities. A second characteristic of the log specification is that in this form of the demand equation, one assumes that the elasticity is the same at any point on the demand curve.

In estimating the demand function, both log and non-log specifications and other variations are frequently used to determine the shape of the demand curve and thus determine the extent of its variations at different price levels.

Block Rates and the Simultaneous Determination of Price and Quantity

The simultaneous determination of price and quantity for products such as water and electricity creates a problem in the specification of the price per unit of these products. A utility typically prices its products under a block rate schedule so that customers pay different prices for various units. The problem is illustrated by a typical rate schedule for water. As usage increases, each additional gallon is priced at the same or at a lower price. An example of a declining block rate would be a charge of $6 for part or all of the first 4,000 gal, $1 per 1,000 gal for the next 4,000 gal, and $0.80

for each additional 1,000 gal. The various possible bills calculated from this schedule are shown in Figure 2(a).

Figure 2(b) shows a graph of the marginal price, which is the price per unit (1,000 gal in this case) for the last unit purchased. The first block is a fixed cost; therefore the marginal price is zero until the quantity consumed is greater than 4,000 gal.

Marginal price is frequently selected as the price variable in elasticity estimates. This practice is justified on the assumption that additional use (or conservation) is based on the price for the additional unit only.* A clear example is seen in the special case of a single block where water is priced at a flat monthly rate. The marginal price is zero, and the customer has no incentive to conserve. In the example in Figure 2(b), a customer contemplating the cost of filling a swimming pool might consider only the additional cost of $0.80 per 1,000 gal.

In other elasticity studies, average price per unit has been used as the price variable. One justification for using this variable is based on the assumption that most utility customers react to total charges and do not know the marginal block rates anyway.† A more important justification is based on theoretical considerations introduced at a later point. In addition to the counter argument that marginal price is more appropriate, criticism of the use of average price is based on an upward bias introduced into the price elasticity estimates.‡ The bias is illustrated by the behavior of average price in Figure 2(c). In a declining block rate schedule, the average price declines as the quantity consumed increases. Regression estimates of price elasticities are based on the assumption that price decreases would cause increases in consumption. To the extent that the regression results reflect the effect of the level of consumption on the price (as opposed to the effect of price on the level of consumption) the relationship is meaningless as an elasticity.

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*Gibbs (1978) justifies the use of marginal price on the basis of a comparison of results from using it and the average price in two otherwise identical equations. The comparisons, however, establish nothing other than the fact that the two variables yield different results. The a priori argument of Howe and Lineweaver (1967) and his own supporting assertions as summarized here remain the basis for the use of this price specification.

†Wilder and Willenborg (1975) present this argument, but following Halvorsen (1975), they also argue erroneously that use of the average price will give the same results as the use of the marginal price. (See earlier reference to Gibbs, 1978.) It can be shown that Halvorsen's mathematical proof is a special case.

‡The possible bias is recognized by Howe and Lineweaver (1967) and Halvorsen (1975) among others. Taylor (1975) provides the most detailed theoretical treatment of the problem, and he is generally followed below. Our exceptions to Taylor's specification of price are detailed later in this chapter under Intramarginal Price and the Lump Sum.

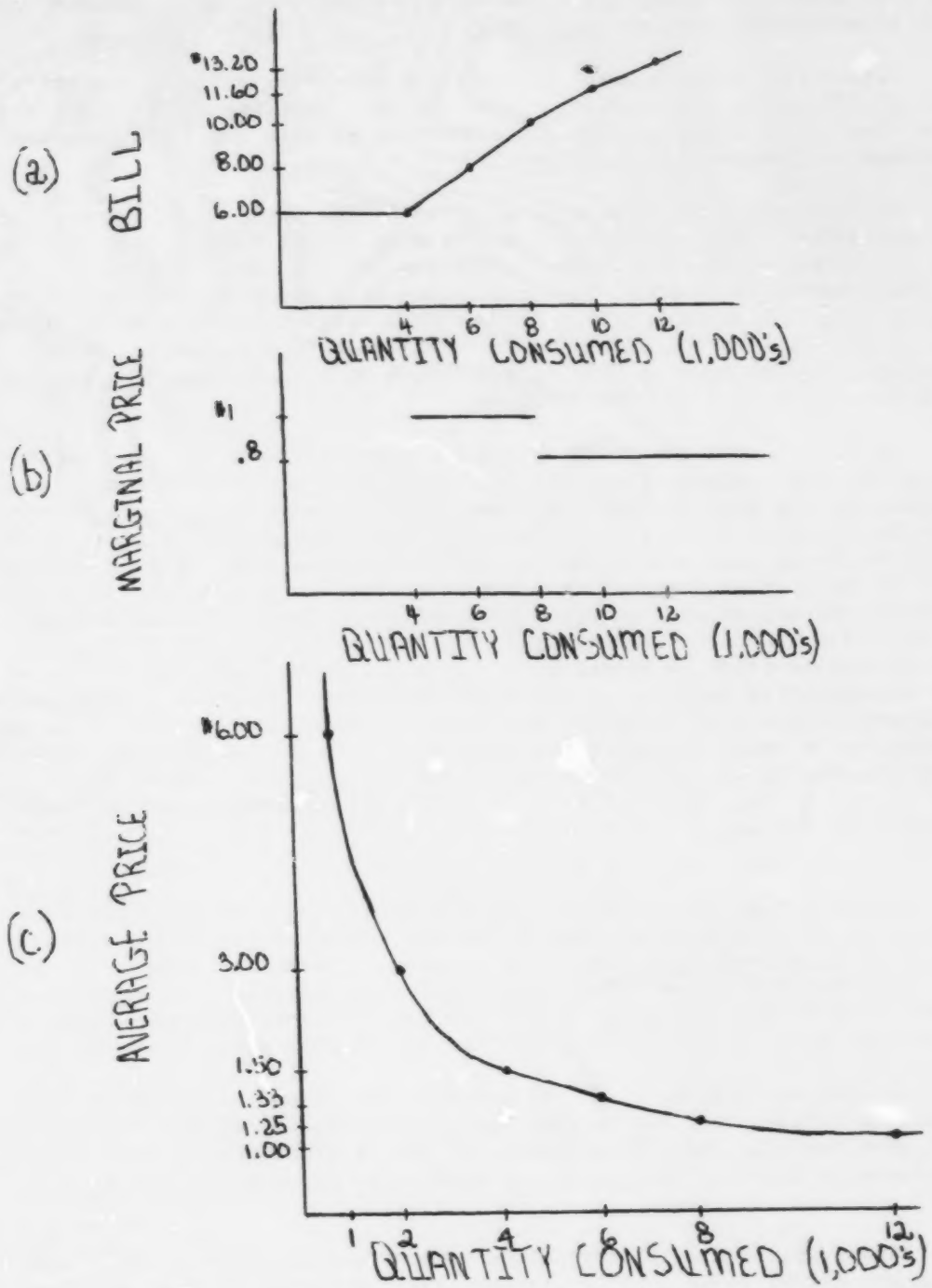

Figure 2. Declining Block Rates, Schedule A.

The problem of simulteneously determining price and quantity also applies to marginal price. Consider, for example, Figure 2(b). Apartment dwellers would tend to cluster in groups of customers consuming relatively small quantities of water--perhaps 4,000 to 8,000 gal. Thus regression results using the marginal price actually paid by a typical population would show a strong association between price and quantity, and the elasticity would tend to be overestimated. To the extent that a large number of customers might be consuming in the initial block with zero marginal price, however, the data base would contain the lowest price for the lowest users, and elasticity estimates could be biased downward or even estimated with the wrong sign.

Price as a Measure of Relative Charges Among Schedules

One solution to the simultaneity problem is to specify price directly from rate schedules. The average price in previous studies was usually defined as total expenditures divided by quantity consumed--that is, the price was determined after the consumption level had been established, or ex post. This caused the bias illustrated in Figure 2(c). To avoid the bias, average price must define the charges under the schedule, not the price actually paid by each customer.

One possible way to specify price in the schedule illustrated would be to select the average consumption of all customers in the data set (6,000 gal, for example,) and to use the bill at this predetermined (ex ante) level to determine the price variable for each customer under this and other schedules. Thus $8 would serve as a proxy for charges under the schedule illustrated, and this price, which represents total expenditure, would be compared with similar calculations of bills under other schedules. The expenditure concept is discussed later; here, it is simply the price stated for a unit of 6,000 gal. As an alternative, the ex ante average price, which would produce the same regression results as the expenditure price, is $1.33 per 1,000 gal, as illustrated for the 6,000 gal consumption level in Figure 2(c).

A similar approach for defining a marginal price that defines the schedule is considered below. First, we consider the extend to which the ex ante average price accomplishes the objective of defining the relative price levels among schedules. The major determinant is the extent to which the rate structures in the data set are based on similar pricing objectives. In general, the rate for the first block reflects fixed cost in servicing the account and paying for capital outlays. Lower marginal rates reflect the lower cost to the utility for extra water purchased. Each utility's rate structure is designed to cover total cost, and a low-cost system, represented by Figure 3, will typically have lower charges for each block relative to the high-cost system as shown in Figure 2 on page 14. In Figure 3, the rate schedule is illustrated based on charges of $4 for the first 4,000 gal or less, $0.80 per 1,000 gal for the next 4,000 gal, and $0.60 per 1,000 gal for everything over 8,000 gal.

Figure 2(c) and 3(c) provide a number of possible price comparisons at ex ante or predetermined consumption levels. All reflect the fact that customers pay less under the schedule used in Figure 3 than do the customers

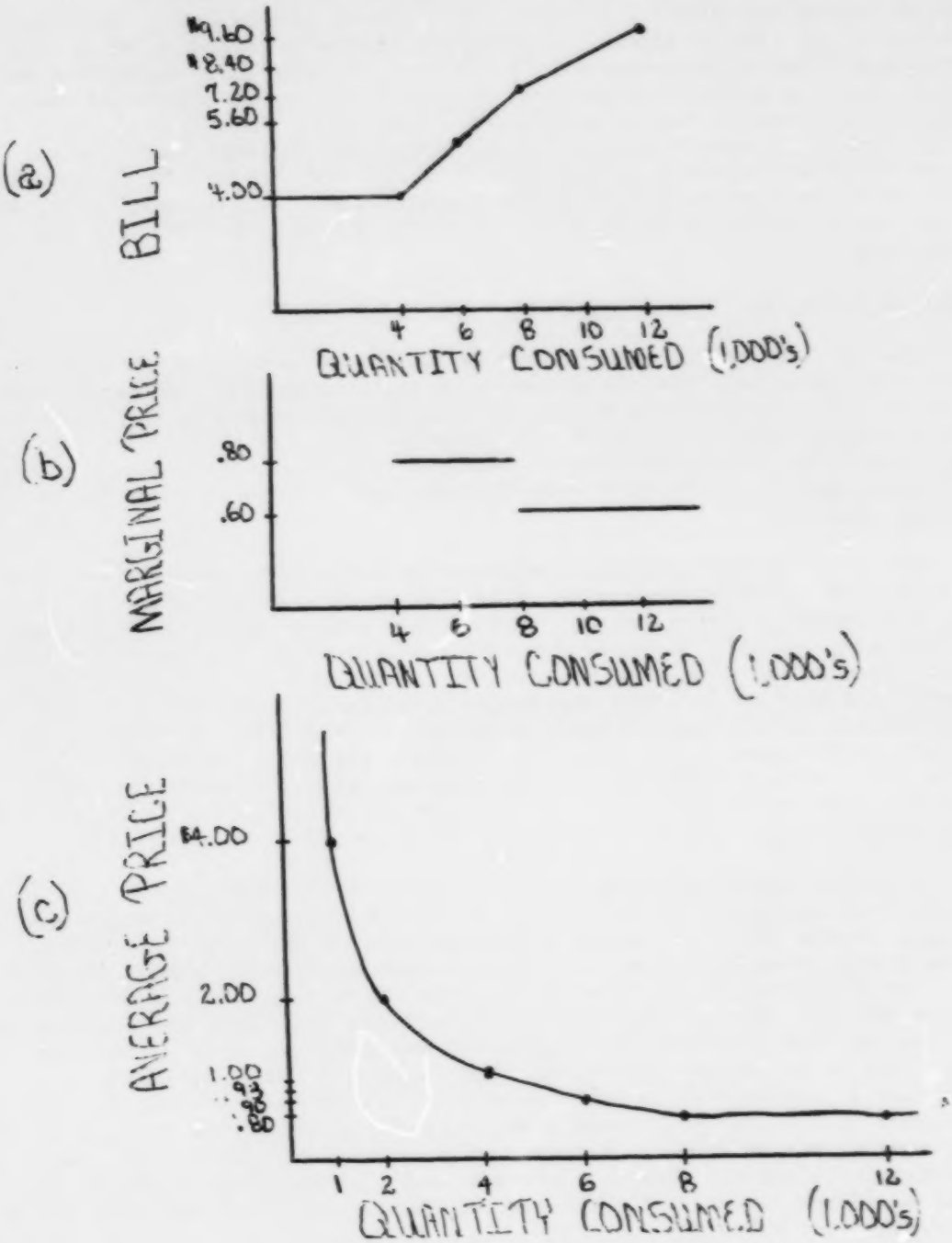

Figure 3. Declining Block Rates, Schedule B.

facing the charges illustrated in Figure 2. By selecting price according to our predetermined criteria, we find the 6,000 gal ex ante average prices of $1.33 and $0.93 for the two schedules. With the empirical definition of the percentage differential described on page 11, the $0.40 difference in average prices under the two schedules is 35 percent. (Note that the same percent differential would have been calculated from the two bills at 6,000 gal.)

The ex ante average price selection is arbitrary in the sense that some other bench mark would produce a different measured differential between the two schedules. For example, there is a 40-percent differential in average prices at the 4,000 gal use level and only a 32-percent differential at the 12,000 gal use level. This limitation, however, is inherent in block rate schedules, because no single price variable can reflect the exact price differential for all of the possible levels of consumption. Nevertheless, any ex ante average price based on any selected consumption level within the range of typical use would provide a measure of the relative level of charges under various schedules to the extent that the marginal price is typically higher in schedules with higher first-block charges.

Whether the average and marginal prices are positively correlated with a roughly proportional allocation of fixed and variable cost to the rate schedules (as in the examples above) for a given data set is an empirical question that will be discussed in the following subsection. The possible case of a random mix of schedules (some with high initial charges and low marginal rates, and others with marginal rates about as high as the average cost in the initial block) would make the ex ante average price either inappropriate or incomplete in comparisons of charges among schedules. The extreme case of a nonproportional mix is illustrated by comparing the inverted block rate structure in Figure 4 with the schedules discussed above.

Figure 4 illustrates an inverted block rate based on charges of $4 for the first 4,000 gal, $1.50 per 1,000 gal for the next 4,000 gal, and $2 per 1,000 gal for each additional 1,000 gal. Increasing blocks are advocated by conservationists as a way to induce consumers to reduce their consumption of water or energy. The average price behaves quite differently for this schedule than for those in Figures 2 and 3. After an initial decline for use up to the minimum charge, average price increases with higher use. The ex ante average price would not be used as a measure of the relative cost of water in this schedule as compared with the other two schedules. The unambiguously higher marginal prices of Figure 4 are the basis for assuming that the inverted schedule would induce conservation.

Relative Marginal Prices--The Problem of Random Block Sizes

The rate schedules of Figures 2, 3, and 4 also serve as a basis for considering the marginal price that applies to the schedule as opposed to the marginal rate a given customer might pay. If all schedules in a data set were based on rate changes at 4,000 and 8,000 gal, as illustrated, the specification of the marginal rate at the mean consumption level of 6,000 gal would provide a simple solution. From Figures 2, 3, and 4, the ex ante marginal rates would be $1, $0.80, and $1.50, respectively.

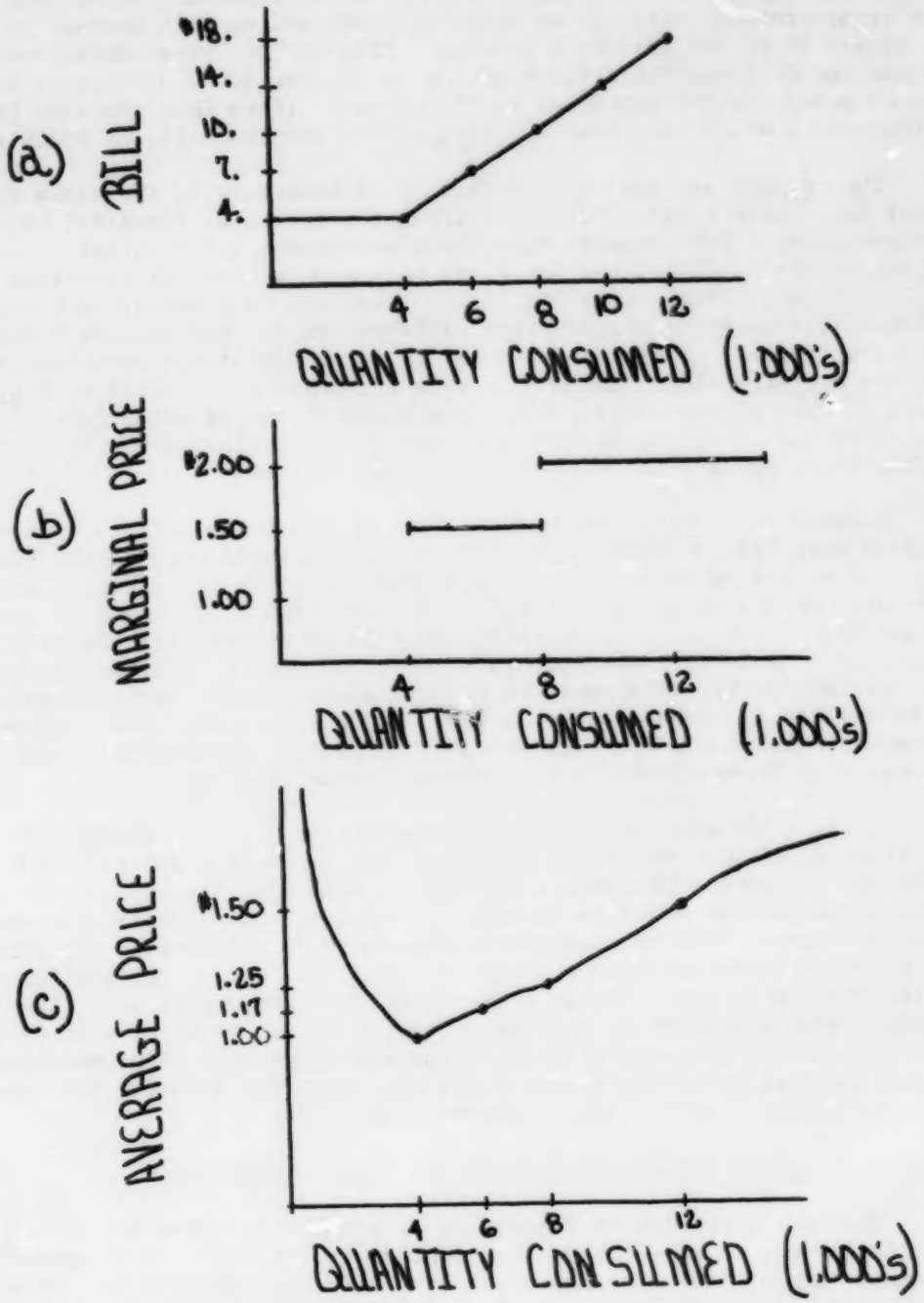

Figure 4. Increasing Block Rates.

There are, however, two problems with a predetermined use level as the basis for identifying marginal prices that would be comparable among several schedules. First, the extra use (which may be associated with a low marginal rate) for many customers is the seasonal demand for lawn sprinkling, which may fall in more than one block. An example is the customer whose average winter use is 6,000 gal and whose average use in hot, dry months is 10,000 gal. Under the schedules illustrated, and if it is assumed that this pattern of use as opposed to a single consumption level is taken as the ex ante bench mark, the appropriate marginal rate for each schedule might be the average of the two marginal rates within each schedule--$0.90, $0.70, and $1.75, respectively, in Figures 2, 3, and 4.

The second and more serious problem is that breaks in the blocks among schedules are randomly scattered. Consider the rate-maker's decision in the (typical) schedules represented by Figures 2 or 3. His objective is to collect some target total revenue per customer, with the constraint that the schedule must take some equitable distribution of fixed and variable production cost among customers. Blocks might have been selected at 2,000-gal intervals up to 10,000 gal, or all of the fixed charges might have been collected in an initial block of 6,000 gal with a single additional block beyond that amount. The problem is specifying a marginal price that is comparable among schedules is to avoid variations based on the arbitrary decisions in rate-making.

The solution is to select a uniform basis for calculating ex ante marginal prices. This part of the charge should be obtained by calculating the rate over a typical range of extra use, rather than selecting some point within the range, since a point is less likely to be uniform among schedules. An example of the type of calculation required is provided by Figure 2(a), where the marginal charge can be calculated directly for the block between 6,000 and 10,000 gal. The difference between the two bills ($11.60 - $8.00) divided by the interval (4,000 gal) is equal to $0.90 per 1,000 gal. This marginal price will be comparable to marginal prices in other rate schedules to the extent that other schedules are based on comparable allocations of fixed and variable cost to the rate schedules. (Recall that ex ante average prices are comparable in Figures 2 and 3, but not in Figure 4.)

Non-Uniform Allocation of Costs in Rate Structures

Although the inverted schedule of Figure 4 serves as an example of a case in which a single variable could not be considered as a proxy for the entire schedule of prices among the three schedules illustrated, a more important constraint for empirical elasticity estimates is found in a similar discrepancy among the ways utilities choose to allocate their costs to rate schedules. The problem is most notably present when the water bill includes all or part of a sewer charge. In the pricing policy adopted by a utility, there is almost equal logic (sometimes influenced by political consideration) for either (1) adding an additional flat charge because it is assumed that the sewer system is virtually all a fixed expense, or (2) using a separate declining rate for the sewer based on the assumption that the household load on the sewer is in proportion to the household use of water. These two cases can be considered with further reference to Figure 2.

First, assume that approximately $4 per sewer customer is required to cover the cost of providing the service. The charge could be made by adding $4 to the first block, or by adding a 50-percent surcharge on to the water bill. In either case, the ex ante combined average price to the sewer customer would be 50 percent higher than it would be to the customer in the same system with no sewer charge. (In the first case, the minimum bill increases from $6 to $10; in the second case, the average price of $8 at 6,000 gal is multiplied by 1.5.) The difference between these two pricing decisions (and implicitly, an important difference in water rates, depending on how the total charge is allocated to the minimum and variable components of the rate) is reflected in the marginal rate relative to the average price.

Because utility rate schedules are not uniform in their concepts and treatment of the fixed and variable components of charges, a single price variable cannot be depended on to define the differentials in charges among schedules. Theory predicts that the customer with the increase in the minimum charge will react somewhat differently from the customer faced with the surcharge.

Income and Substitution Effects

An increase in the fixed charge would tend to reduce consumption even though there was no change in the marginal rates. Theoretically, a reduction in water consumption would be predicted because of the income component of the price effect. At higher prices, the household will cut back on water and all other goods to stay within the budget.

The same is true for the 50-percent surcharge, because the higher total charge will induce a reduction in water and/or other goods consumed. A higher price of any good and a fixed budget will require economies somewhere, and thus cause an income effect. With the surcharge, however, the household would be expected to cut back on water expenditures to a greater extent than it would with the fixed-charge increase, even though the total bill will have increased the same amount for both households and the income effect would be the same for both. In the second case, the marginal price is 50-percent higher than in the first. We predict that the second household will also make fewer purchases at the margin. Such behavior is known as the substitution component of the price effect. The two separate effects of income and substitution are additives in the total price effect.

Summary and Conclusions

Thus theory predicts that water consumption will decrease both with (a) an increase in average price an no change in marginal prices, and (b) an increase in marginal price and no change in average prices. A theoretically appropriate price specification will therefore require that both average and marginal rates be considered. One possibility is to specify both variables in an estimating equation. The example here, however, illustrates the objective common to all possible specifications. Two variables should be used to define (or serve as proxy for) the level and slope of the function representing the total bill.

The need for two variables in the price specification stems from the two components--income and substitution effects--that make up the total price effect. For utility products priced under a block rate schedule, the average and marginal components of price will produce differing income and substitutional effects. In this respect, the price for a utility product is uniquely different from the prices of typical goods such as toothpaste, where the average and marginal prices are identical and any price impact includes both income and substitution components.

Use of ex post price will result in different prices being paid by different customers under identical rate schedules, and use of an ex ante price will result in different prices only if the customers are subject to different rate schedules. Ex post prices have been used in most previous studies, and the major disagreement on methodology has been over whether the marginal or average price was the appropriate variable. Taylor (1975) in his theoretical critique, which still applies to errors in more recently published elasticity estimates, places emphasis on correctly defining variables--ex ante as opposed to ex post--and using more than one variable to define a rate structure.

Though emphasis has been limited in this subsection to the ex post and ex ante definitions of marginal and average prices, two additional price variables are considered later under Intramarginal Price and Lump Sum. They are conceptual variations of and alternatives to the use of average price for defining price level.

DATA SET AND DEFINITIONS USED IN THIS STUDY

Examples in the previous subsection, with the exception of the inverted rate structure, are consistent with our statewide sample, which contained about 60 rate schedules (some for water only and some for the combined water and sewer) provided by more than 40 utilities. All schedules have a fixed charge for a minimum purchase. Initial blocks were between 2,000 and 5,250 gal, and the number of blocks ranged from two to seven. Sever rates were mixed between schedules with declining blocks similar to the water rates and schedules with all or most of the sewer charge in the initial block.

More than 700 observations of household water consumption showed monthly use to average about 6,000 gal annually and 5,000 gal during the winter months. Extra use in the hottest months averages about 4,000 gal in samples with seasonal variations in usage patterns. These observations served as the basic justification for using the ex ante bench marks of (1) 6,000 gal for calculating the average price or total expenditure variable, and (2) 6,000 to 10,000 gal as the range for calculating marginal price.

An analysis of the validity of the ex ante bench marks is provided later in this chapter under Elasticities of Water Demand. Preliminary indications of validity were obtained from an analysis of possible ex ante specifications. Table 1 provides an example of one of the factors considered.

Table 1 shows the correlation coefficients obtained by comparisons of ex ante prices for various consumption levels. The correlation of .994

TABLE 1. CORRELATION COEFFICIENTS BETWEEN HOUSEHOLD WATER BILLS AT VARIOUS CONSUMPTION LEVELS, RATE SCHEDULES OF 78 WATER UTILITIES IN ALABAMA

Consumption level (gal)	Consumption level (gal)							
	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000
4,000	0.928	0.918	0.880	0.842	0.804	0.769	0.736	0.705
5,000		0.987	0.972	0.952	0.930	0.907	0.883	0.860
6,000			0.994	0.986	0.963	0.944	0.924	0.903
7,000				0.996	0.987	0.974	0.959	0.943
8,000					0.998	0.990	0.979	0.967
9,000						0.998	0.992	0.984
10,000							0.998	0.993
11,000								0.999

between prices at 6,000 and 7,000 gal, for example, would indicate that the ex ante price based on 6,000 will be an almost perfect proxy for the price actually paid by all customers actually using 7,000 gal--that is, the ex ante price will measure the price differential among schedules. Thus the table indicates that a bench mark level of 4,000 gal would not serve as a very accurate indicator of level of charges faced by customers consuming 10,000 gal per month (correlation of less than .8, obtained by reading across the top row). Conversely, the high correlations among expenditures in the 5,000- to 8,000-gal range indicated why there was virtually no difference in the results expected (and later actually obtained) from any of the bench marks in this range. The lower correlations for 4,000 gal in comparison with bills for 5,000 and above stem mostly from minimum charges based on 5,250 gal in a number of samples and from variation in the proportion of fixed-to-variable charges among rate schedules.

A similar correlation matrix (not shown) was used to verify the fact that the bench mark selected for specifying the ex ante marginal price was as good or better than alternative bench marks. Correlation between the marginal price calculated from the 6,000 to 10,000 gal range and other ranges were generally greater than .94.

INTRAMARGINAL PRICE AND THE LUMP SUM

The arguments for the use of two prices to define a rate schedule were drawn primarily from Taylor (1975) in his theoretical critique of price variables. In this section, we consider his concept of the distinction between the intramarginal and marginal components of price. Our primary concern is with bridging the gap between this reasonably clear concept of price and how the concept can be converted into empirical specifications.

The Concept and Taylor's Specifications

The distinction between intramarginal and marginal price can be seen in Taylor's instructions for specifying the variables. Refer to the rate schedule in Figure 2 and assume that a customer is using 6,000 gal of water per month. The intramarginal price is defined by Taylor as the initial expenditure or amount paid up to but not including the block of actual consumption. In this case, the intramarginal price is the bill associated with the first block, $6. Taylor also noted that the intramarginal price could be stated as the average price per unit within the initial block or blocks and that the two specifications would produce identical results in regressions--it makes no difference whether price is stated at $1.50 per 1,000 gal or $6 per 4,000 gal. Marginal price is that within the block of consumption, or $1 per 1,000 gal.

Taylor's intramarginal price represents the sunk cost in the customer's bill, or the reduction in his household budget that will limit his expenditures on water and other goods. Taylor believed that this price variable would measure the income effect discussed earlier. He associated the marginal price with the substitution component of the price effect. Although it is demonstrated below that the intramarginal price would cause only part of the income effect (i.e., the marginal price would cause some income

effect), it is clearly desirable to find the extent to which the two components of price (intramarginal and marginal) affect consumption differently. In short, it would be helpful to know if a 50-percent increase in marginal price would have a greater effect on conservation than would an equivalent increase in the first block, as discussed in the example on sewer charges.

Nordin's Lump Sum Specification

Nordin (1976) proposed a modification to Taylor's specification of the intramarginal price; he identified the sunk cost part of the rate as a lump sum. He defined the lump sum as Taylor's initial expenditure less the product of the marginal rate times the quantity taken up to the last block. The lump sum for a customer consuming 6,000 gal under the rate schedule of Figure 2 would be $2: 4,000 gal at the marginal rate of $1 per gal is subtracted from the initial expenditure of $6.

The lump sum specification adds clarity to the concepts, since it is closer to real-world pricing practice and is especially similar to a new trend in rate structures now gaining in popularity among energy utilities. Utilities charge for making their service available; in residential rates, the usual practice is to cover most of the fixed investment and administrative cost in the minimum charge. Some but not all rate structures now spread the fixed cost over several blocks. A trend toward a flat customer charge on energy use makes the rate-making process more explicit. The lump sum calculated under a rate structure with a customer charge would simply identify the customer charge. Under most water schedules, the lump sum will be an estimate of the fixed load in price schedule.

From a theoretical standpoint, Nordin claims that the lump sum is superior to the intramarginal price on a technical basis, but he assumes that Taylor is correct in the belief that income and substitution effects can be separated. Since we do not believe these components of price effects can be segmented, our primary interest in the lump sum is that it appears to be a logical conceptual specification for separating the marginal and intramarginal price effects. Technical differences in the two specifications will be further discussed after modifications are made in the way the variables are specified.

A Common Ex Post Error

Both Taylor and Nordin would obtain the price variables for each customer directly from the rate schedules on the basis of each customer's use level. In spite of Taylor's emphasis on this pitfall, such a step would lead to the simultaneity bias, as can be seen in comparisons of Taylor's intramarginal prices for different customers under the rate schedule of Figure 2. A customer using 10,000 gal per month would have an initial expenditure of $10 (the bill for 8,000 gal for the blocks up to the block of consumption). This amount is equivalent to an initial price of $1.25 per 1,000 gal. In the example above, in which a customer was using 6,000 gal, the initial expenditure was $6 and the average price of the initial expenditure was $1.50 ($6 ÷ 4,000 gal). Regression using the initial expenditure to explain demand would produce a positive correlation between price and quantity, those using

the average intramarginal price would produce a negative correlation, and both correlations would reflect the effect of quantity on price instead of vice versa. The bias in Nordin's lump sum or the marginal price variables could be demonstrated with similar comparisons.

The Correct Conceptual Specifications and Empirical Ambiguities

The error in the literal interpretation of the instructions of Taylor (1975) for specifying variables appears to be an oversight on his part. The initial expenditure and average price in the initial blocks are statistically equivalent (a condition emphasized by Taylor) if and only if: (1) there is only one intramarginal price and one marginal price per schedule and (2) the initial block or blocks in each schedule are for an identical quantity. Given the random distribution of breaks and the size of blocks in various rate schedules, the conditions will obtain only under ex ante specifications of the initial block. Similarly, the range of use on which the marginal price will be specified must be determined ex ante.

An empirical ex ante definition of the initial block could be based on the average size of all initial blocks as defined by Taylor, which would be about 4,000 gal in our data set. As noted in the previous subsection, however, there is essentially no difference in the regression results expected if the initial block is defined as 5,000 or 6,000 gal instead of 4,000 gal. We have therefore elected to define the initial block as 6,000 gal and thereby emphasize that the conceptual distinction between Taylor's initial expenditure and the traditional notion of the average price (derived from the average expenditure) cannot be extended to an empirical distinction for our rather typical data set.

The 6,000 gal consumption level is also used to calculate the ex ante lump sum. In specifying (i.e., estimating) the fixed load of a given rate schedule, calculations based on the average use level are at least as sound as those based on an initial expenditure. The reason is that the initial block or blocks are arbitrarily selected by the rate maker. The random selections in rate decisions will tend to understate the lump sum for any rate structure which spreads the fixed charge over a higher level of use, such as 5,000 gal, relative to one with the entire load in an initial block of 2,000 gal.

The ex ante consumption range of 6,000 to 10,000 gal for defining the marginal price is also retained from our previous definition. There are no significant conceptual or empirical differences in marginal price, regardless of the conceptual model used for empirical estimates.

Figure 5 shows the original rate schedule of Figure 2(a) in dashed lines and how the schedule is restructured in the calculation of the ex ante variables. The major purpose of the figure is to summarize the conceptual differences among the average price, the intramarginal price, and the lump sum, and to clarify the nature of the empirical ambiguities of these variables.

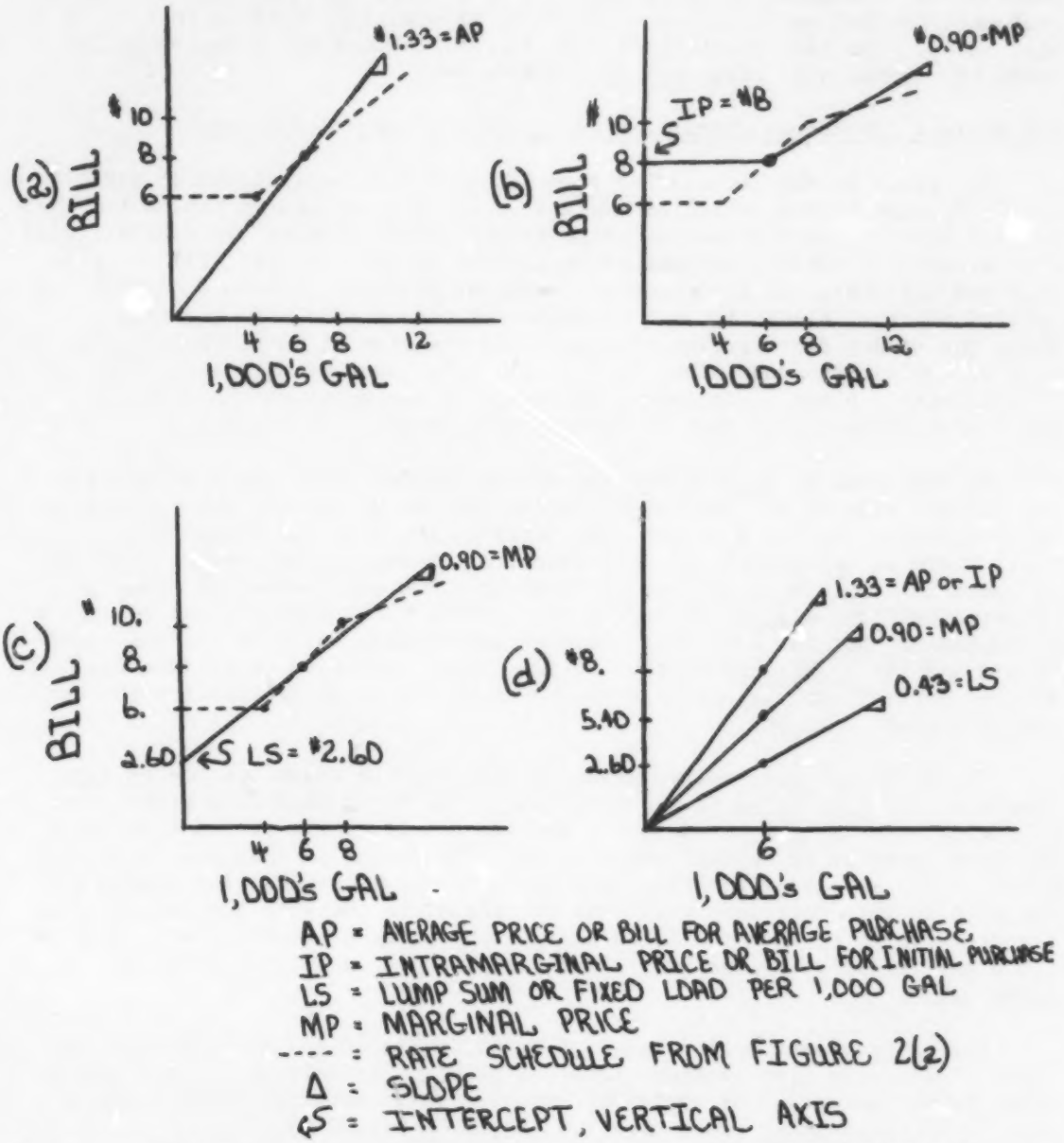

Figure 5. Ex ante price variables calculated from the rate schedule of Figure 2(a). Note: Charges under the schedule are $6 for all or part of the first 4,000 gal, $1 for each additional 1,000 gal up to 8,000 gal, and $0.80 for each additional 1,000 gal. To compare prices under this schedule with dissimilar blocks in other schedules, the initial block is defined as 6,000 gal, and the marginal price is calculated directly for the 6,000 and 10,000 gal in all schedules.

The solid line in Figure 5(a) illustrates the ex ante average price conceptualized as the slope of the average expenditure function. The average bill of $8 for 6,000 gal converts into a price of $1.33 per 1,000 gal so the function is drawn through the origin with a slope of 1.33. The price illustrated contain both marginal and intramarginal components of the rate schedule and is the correctly specified equivalent of the average price used in previous studies that assumed (1) that a schedule can be quantified in a single variable and (2) that the average price as opposed to the marginal price is the one that influences consumption.

The difference between block rates and conventional prices is easily seen in the illustration. The single price for a conventional good such as toothpaste selling at $1.33 per tube would also be illustrated by the solid line in Figure 5(a). For toothpaste, however, the single price is both the average and the marginal price. The basic problem in defining the rate structure in a single variable is to match the slope of the actual rate schedule with a straight line through the origin.

Figure 5(b) is one possible conceptualization of the two-variable specification of the rate structure proposed by Taylor (1975). Here, the intramarginal price is illustrated as the initial expenditure of $8 for a range of consumption in which the marginal price is zero, i.e., the slope of the function is zero. Beyond 6,000 gal, the marginal price of $0.90 (calculated as the average of marginal prices between 6,000 and 10,000 gal) is represented by the slope of the solid line. The use of the intercept and slope more closely approximates the actual rate schedule.

The modification proposed by Nordin (1976) is illustrated in Figure 5(c). The solid line here is the same marginal price of $0.90 extended to the vertical axis. The intercept at $2.60 is the lump sum. Conceptually, the total bill is separated into two distinct components--the variable charge and the fixed charge. In effect, Nordin's specification eliminates the double-counting in Taylor's intramarginal price. The price function is more precisely defined by the intercept and the slope of a straight line.

The segmentation of price into fixed and variable components (the intercept and slope) is not unambiguous when considered in the context of a multiple regression. Figure 5(d) shows each of the variables as either slopes or intercepts to illustrate this point. The intramarginal price, or intercept in Figure 5(b) is identical to the average price function in Figure 5(a). In a regression, the percent differential among bills is the same as among prices per gal. The marginal price in Figure 5(d) is the same as in Figure 5(b) and (c) except it is now drawn through the origin. As indicated in the diagram, the marginal price is equivalent to $5.40 of the average bill (6 x $0.90 = $5.40). The lump sum is converted to the average amount of fixed charge per 1,000 gal ($2.60 ÷ 6 = $0.43) and drawn as a slope rather than an intercept. Each variable is independent; any or all of the variables could be included in a regression along with other unrelated and independent variables to test the extent of their influence on water consumption.

Figure 5(d) also shows the relationship among the various price variables. The lump sum plus marginal price is equal to the average price when these variables are considered as parts of the total bill (the intercepts) or as fixed and variable components of the price per unit (the slopes). The intramarginal price and average price are identical here by definition; however, any redefinition of the intramarginal consumption block to more closely approximate the block of up to but not including the block of actual consumption would not alter its equality to the lump sum plus marginal price. Both the intramarginal and average price concepts are to measure the difference in the overall level of charges among schedules.

Finally, Nordin's refinement which equates the parts to the whole is based upon the notion that the income component of the price effect can be and should be isolated. This in turn, is based on the notion that only the substitution effects are relevant in the elasticity measurement. If this is not the case, then the older issue of whether the average price or the marginal price is the appropriate price variable in elasticity estimates is more relevant than Nordin's lump sum-marginal price dichotomy. A major contribution of the Taylor price specification is that both the marginal and average prices are theoretically relevant in the consumption decision.

Figure 5(d) provides a useful insight on the relationship between the average price and the marginal price in a block rate structure. The marginal price is the average price less the built-in fixed charges; to the extent that this price is relevant to all or part of a customer's decision on the amount of water to consume, the price effect would contain both income and substitution effects as in the price of a conventional good. Any influence on consumption exerted by the lump sum would be an income effect; however, this effect would be in addition to, not instead of, other price impacts. Moreover, the income effect of a utility's change in the fixed charge would still be a price impact and should be included in the price elasticity.

The questions raised above as to which variables are relevant to the consumption decision are subject to empirical testing. Since the intramarginal and average prices are identical, a test of Taylor's model is a test of the original and ongoing controversy over the appropriate specification of price--marginal or average. If both prices are included as regressors along with other independent variables such as income and occupants in explaining water demand, the results should shed light on both the relative importance of the variable and what they actually measure.

The question of what a variable measures (as opposed to the hypothesis of what it should measure) is illustrated by the lump sum. As conceptual defined, we would anticipate a reduction in water consumption as the fixed charge increases, all else equal. As illustrated in Figure 5(c), there is a single price of $0.90 per 1,000 gal plus this differential charge for having the service available. An alternative interpetation is offered in Figure 5(d), however. We could interpert this schedule to have a basic (average) price of $1.33 per 1,000 gal with a discount of $0.43 per 1,000 gal on additional use. Since the lump sum enters the regression equation as an independent variable, it is not clear whether it will measure the negative impact of a penalty charge or the positive impact of a quantity discount.

Summary and Conclusions

Neither the intramarginal price nor the lump sum can screen out the income effects of a price schedule because the marginal price gives rise to both income and substitution effects. Also, the specificaiton of the rate schedules with two variables is still essential because the fixed and variable components should, *a priori*, cause different amounts of price impact. In addition, this anlysis reinforces an earlier point--that the general concept of elasticity is to measure the total price effect without regard to whether it comes from the income of the substitution components of the price effect.

No sound *a priori* grounds appear for declaring either the marginal or the average price in a rate schedule as a price equivalent to MP = AP in unit-priced goods, as has been done in most published studies. There are also conceptual and even more formidable empirical barriers to specifying two price variables that define a schedule of prices and at the same time clearly distinguish between what is the marginal component of the rate and what is not. These limitations, however, should not obscure the real issue, which is to answer elasticity questions such as whether and how much an increase in the fixed charge will effect consumption, as opposed to a comparable increase in variable charges.

EMPIRICAL RESULTS--COMPARISONS OF ALTERNATIVE MODEL SPECIFICATIONS

This subsection addresses the central issues through a comparative analysis of several specifications of estimating equations using the alternative price specifications developed to this point. With other determinants held constant, price impacts are estimated in the following models:

(1) $Q = f(AP)$
(2) $Q = f(MP)$
(3) $Q = f(AP, MP) = f(IP, MP)$
(4) $Q = f(LS, MP)$
(5) $Q = f(AP, LS)$

The empirical ambiguities noted earlier are resolved by interpretation of the results within the context of each model.

Since *ex post* definitions are used for comparison with the correctly specified *ex ante* variables, the data set was reduced to observations of household customers with average monthly use in excess of the minimum charge, thus eliminating samples with MP = 0.

All estimating equations are in the general form:

$$\ln Q = B_0 + B_1 \ln AP + B_2 \ln MP + B_3 \ln INC + B_4 \ln PEO$$

where Q is the average monthly consumption (which is explained for five winter months and five summer months as well as on an annual basis), coefficients of the price variables are direct estimates of the elasticities, B_3 is

an estimate of the income elasticity (INC is on household income from all sources), and PEO is the number of household occupants.

Table 2 reports results from model specifications based on the assumption that one variable is sufficient to define the price under a schedule. The ex post specifications are based on the prices actually paid by each customer in the sample. The elasticity associated with the average price is in the range of -0.4 to -0.8 and is consistent with estimates reported in previous studies that we consider invalid because of the simultaneity bias. Elasticities based on the marginal rates in the range of actual consumption indicate no significant relationship between this price and the quantity taken in winter. Even the significant coefficients for annual and summer use indicate that the marginal price could have little influence on consumption. Conversely, considering the bias, the level of use has little influence on the marginal rate in this data set.

In contrast to the biased estimates, the ex ante average price specifications indicate a price elasticity of about -0.2, and the marginal price has no influence on consumption levels. A comparison of the ex post and ex ante specifications indicate the extent of the bias from the misspecification of price.

Other effects of misspecification can be seen in comparisons of coefficients for the income and occupant variables. In particular, the estimate of the income elasticity has a downward bias as a result of the misspecified average price. In addition, the coefficients of determination (R^2's) are inflated as a result of the quantity taken, which explains the average price rather than vice versa.

Finally, a comparison of the R^2 between ex ante specification for average and marginal price for each season indicates that even though average price is significant, the variable adds very little to the explanatory power of the entire equation.

Table 3 presents results obtained by defining the rate schedules with two variables. The ex post specifications in the upper part of the table have no validity in explaining consumption, but they are of interest as a basis for comparisons with ex ante specifications. They are also similar to results obtained (but not shown) from the literal or ex post specification of Taylor's average price in the initial expenditure. Regressions specified with Taylor's optional intramarginal price (the ex post initial expenditure) in combination with marginal price changed both the magnitude and signs of the price coefficients but were otherwise similar. In all three combinations of two misspecified variables, the typical effect was to increase the R^2 in comparison with results from the ex post average price specification in Table 2. Opposite signs on the price variables are attributed to an interdependence between the price variables in all three combinations.

The results in the second three regressions in Table 3 can be viewed as either a test of Taylor's conceptual model with intramarginal and marginal price, or as a test to determine whether average or marginal price, neither, or both influence the customer's behavior. (The IP in this case is either

TABLE 2. REGRESSION COEFFICIENTS EXPLAINING WATER CONSUMPTION WITH A SINGLE PRICE VARIABLE

Specification of prices	Period	Price elasticity		Income	No. of household occupants	R^2
		AP	MP			
Ex post	Annual	-0.55	---	0.16	0.34	0.51
	Summer	-0.40	---	0.20	0.43	0.44
	Winter	-0.76	---	0.11	0.34	0.62
	Annual	---	-0.13	0.24	0.48	0.34
	Summer	---	-0.16	0.26	0.48	0.33
	Winter	---	-0.05*	0.20	0.50	0.32
Ex ante	Annual	-0.18	---	0.23	0.48	0.34
	Summer	-0.19	---	0.26	0.49	0.33
	Winter	-0.17	---	0.19	0.50	0.33
	Annual	---	-0.05*	0.24	0.48	0.34
	Summer	---	-0.01*	0.26	0.48	0.32
	Winter	---	-0.02*	0.20	0.50	0.32

*Not significant at 0.025 level.

TABLE 3. REGRESSION COEFFICIENTS EXPLAINING WATER CONSUMPTION WITH RATE SCHEDULES DEFINED BY TWO VARIABLES

Specification of price	Period	Price elasticity and variable		Income	No. of household occupants	R^2
		Variable No. 1	Variable No. 2			
Ex post	Annual	-0.60 AP	+0.19 MP	0.16	0.39	0.52
	Summer	-0.40 AP	-0.05*MP	0.20	0.43	0.44
	Winter	-0.91 AP	+0.41 MP	0.09	0.29	0.67
Ex ante	Annual	-0.31 AP/IP	+0.19 MP	0.23	0.47	0.35
	Summer	-0.31 AP/IP	+0.17 MP	0.25	0.47	0.33
	Winter	-0.32 AP/IP	+0.21 MP	0.19	0.49	0.33
	Annual	-0.02*LS	+0.04*MP	0.24	0.74	0.34
	Annual	-0.18 AP	-0.01*LS	0.23	0.48	0.34

*Not significant at 0.025 level.

the initial expenditure or average price in the initial expenditure.) The fact that the coefficients are all significant appears to support Taylor's analysis indicating that both intramarginal and marginal elements of price contribute to the consumption decision. The opposite signs and interdependence between the price proxies are inconsistent with a clear division of the rate into two components, as envisioned by Taylor. Interdependence or multicollinearity will tend to create opposite signs on marginal and average prices in the regression results. There is no indication that either initial or total expenditures will measure an income effect.

The opposite signs on the two price variables preclude a straightforward interpretation of the results. It is apparent from a comparison of R^2's among the various equations specified (with either or both ex ante average and marginal price) that marginal price contributes very little to the estimating power of the various models. It therefore appears that average price specified alone provides an adequate specification of relative charges under various price schedules in this particular data set.

A sample of results using the lump sum as one of two variables used to define rate schedules is reported in Table 3. Results obtained from ex post specifications (not shown) were similar in the respect that the lump sum was small and insignificant regardless of the way the model was specified.

When the lump sum is specified with the marginal price, as suggested by the conceptualization of Nordin (1976), there is no evidence of an income effect associated with the fixed charge in the rate schedule. This could be because the fixed component is unimportant, as is the marginal price in isolation; or the results may stem from the fact that both variables proxy the same thing (that is, how the discount or lower rate differs from the overall level of charges). In either case, the variables in combination provide no information on the overall level of consumption. On the other hand, if the lump sum is specified with average price and interpreted as a discount for quantity purchases, we are lead to the conclusion that the overall charge influences consumption, but that the mix or fixed and variable charges is insignificant for this particular data set.* These results are consistent with the interpretation above based on various combinations of the average and marginal price.

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*More important, perhaps, is that these results are not inconsistent with the use of the lump sum or some other variable in other data sets to obtain usable estimates of how the mix of fixed and variable charges influences consumption differently from the overall level of charges as indicated by the LS, by accident rather than design, is a measure of the mix of fixed and variable charges in the rate structures of this data set. Two more explicit mixed variables, lump sum/expenditure ($2.60/$8.00 in Figure 5(c)) and 1.0 dummy variables, which identified samples with the highest or lowest proportion of fixed charges in the mix, as indicated by ratios from the variable lump sum/expenditure, were specified and tested in several equations similar to those reported. No evidence was found that the mix had any influence on consumption independent of the consumption explained by average price.

Conclusions

In summary, the comparative analysis of results from various price specifications indicates that the use of *ex ante* average prices alone should provide reasonably accurate estimates of elasticities in this data set. This conclusion is based on tests indicating that average price explains the price-associated variations in consumption so well that several proxies identifying variation in the mix of the fixed and variable components of the rates make no sifnificant contribution to explaining demand.

The single-variable determination is not consistent with *a priori* expectations and may reflect a special case where the marginal price as opposed to average price is simply an insignificant influence in the customers' decisions. The marginal rate cannot be written off as unimportant, however, because average price contains both intramarginal and marginal components of the rate. The interrelationship between average and marginal price suggests that the variables are not statistically independent and that either could explain part or all of the impact of the other. Results from previous elasticity studies that assume a single price is a sufficient measure of price differential among schedules and assert that either the average or marginal price is the appropriate measure are subject to errors that could substantially understate the true elasticity, even when sufficient precautions are taken to avoid misspecification of the variables. The inadvertant misspecification of price variables remains a pitfall even when the problem is clearly recognized. Misspecifications lead to substantial overstatements of price elasticity and distort the estimates of income elasticity and the impacts of other determinants.

The conceptual foundation for the use of two price variables provided by Taylor (1975) and the modification suggested by Nordin (1976) are major steps toward correcting the possible errors in previous work. Neither approach, however, provides a clear division of price into the intramarginal and marginal components. An alternative approach is to specify price as (1) one variable (such as average price) that will explain the consumer's behavior relative to the purchase of goods with a single unit price, and (2) another variable (such as the lump sum) that specifies the difference between a unit price and the scheduled price. The objective is to uncover any unexplained difference in consumption explained by the difference between average and marginal price.

USE OF PRICE ELASTICITIES IN MAKING POLICY AND MANAGEMENT DECISIONS

The validity of results obtained earlier from *ex ante* average prices alone are given further consideration here in the context of using price elasticities to make policy and management decisions. Since the end use of the price proxy is in the price elasticity estimate, we move directly to improvements in the final estimates. Results are reported from subsets of the data that (1) illustrate findings more useful than the elasticity estimates per se, and (2) provide independent evidence that the estimates are reasonably accurate.

Price Elasticity Results

Customers with zero ex post marginal prices were deleted from the sample in the previous estimates because of the possible distortion to results obtained with ex post marginal price. Since marginal price is dropped from consideration in this section (and, in any event, would have been derived from the schedule), these samples were replaced in the data set and equations were estimated again. Results comparable to the ex ante average price specification in the previous subsection are presented in the first three equations of Table 4. These variables are specified in logarithms, so the coefficients of the price and income variables constitute one set of elasticity estimates. Results from the second three equations were obtained from the same variables, with the estimating equation specified in additive (as opposed to the multiplicative) form. Elasticities were calculated from these coefficients at the mean use, price, and income.*

An interpretive evaluation of the results from each form of the model suggest that the price elasticity is about -0.2, with no difference between summer and winter. The income elasticity is almost +0.3, and it is significantly higher in summer than winter. From the t-values and other tests reviewed below, it appears that the multiplicative form provides a better fit and superior estimates of the price and occupant coefficients. The additive form is somewhat better for income.

Further modification of the variables or the estimating equation could possibly produce a better fit of the data, but it is not likely that the interpretation could be made more definitive. Furthermore, the accuracy of these estimates is sufficient for any plausible applications. A reasonable expectation for elasticity estimates derived from several market areas is that they provide a general description of the response to be expected from consumers as a result of changes in income or rate schedules. They are no more than a point of departure for a specific decision on rates or a forecast for a specific utility.

The finding that price elasticity is -0.2 instead of -0.6 indicates that price affects consumption much less than has been indicated in other studies. A utility facing a need for an increase in revenue of 5 percent would have to raise rates only 6.35 percent if price elasticity were -0.2, and 16.16

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*The mean annual, summer, and winter use is 6,061, 6,571 and 5,346 gal, respectively. Average price per 1,000 gal is $1.32, and average family income is $12,300.

TABLE 4. COMPARISON OF ELASTICITY ESTIMATES FOR ANNUAL, SUMMER AND WINTER WATER USE USING MULTIPLICATIVE AND ADDITIVE FORMS OF THE ESTIMATING EQUATION

Model	Dependent variable	Constant	Average price	Income	No. of household occupants	R^2
Multiplicative	Average annual use	5.92	-0.20 (-3.43)*	0.24 (9.14)	0.47 (13.95)	0.34
Multiplicative	Monthly summer use	5.78	- .22 (-3.55)	.27 (7.32)	.46 (12.70)	.33
Multiplicative	Monthly winter use	5.17	- .19 (-3.09	.20 (7.32)	.49 (13.94)	.32
Additive	Average annual use	2729	-659 (-2.24) ((-.14))*	139 (10.38) ((.28))	848 (12.16)	.30
Additive	Monthly summer use	2747	-650 (-1.89) ((-.13))	170 (10.69) ((.32))	888 (10.71)	.28
Additive	Monthly winter use	2703	-644 (-2.60) ((-.16))	95 (8.33) ((.22))	794 (13.30)	.29

*The t-values are in single parentheses, and elasticity estimates calculated for the additive model are in double parentheses.

percent if price elasticity were -0.6.* Thus a utility may have more latitude in increasing their rates than some recent studies have indicated.

Most policy issues require a less general description of consumer response than the one provided by elasticity estimates. A utility may wish to know whether there is some threshold price level at which higher prices become a significant deterrent to consumption, or how higher rates can be expected to influence revenue from low-income sectors of their service area. Such information is only partially available from a single elasticity estimate. More relevant inputs are available from a direct examination of the issues.

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*This calculation is based on the assumption that price elasticity remains constant throughout the entire range of the price increase. The equation is derived as follows:

R = current revenue
Q = current quantity consumed
P = current price
e = absolute value of price elasticity
g = required percentage increase in revenue
b = percentage increase in price

Current revenue is equal to current quantity consumed multiplied by current price.

$$R = Q \cdot P$$

If there is a need to increase revenue requirement by g, then the new revenue will be (1 + g) R. The new price will be P (1 + b), and consumption will drop to Q (1 - be). Thus the following equation holds:

$$(1 + g)\ R = Q\ (1 - be)\ P\ (1 + b)$$

and

$$(1 + g)\ R = Q \cdot P\ (1 - be)\ (1 + b)$$

since $R = Q \cdot P$

$$(1 + g) = (1 - be)\ (1 + b)$$

solving for b

$$b = \frac{1 - e \pm \sqrt{(e - 1)^2 - 4\,eg}}{2\,e}$$

Applications of Demand Analysis to Policy Issues

A direct approach to the threshold question is to estimate the shape of the demand function rather than an elasticity coefficient. The extent to which groups of customers behave differently under different rate structures is obtained by substituting rate structure dummy variables for the price variable:

$$Q = f(D_1, D_2, \ldots, D_6, INC, PEO)$$

where D_1 is given a value of 1 if the customer faces a rate schedule that charges a monthly rate between \$5.51 and \$6.50 for 6,000 gal, otherwise D_1 is 0. D_2 through D_6 similarly represent schedules charging \$6.51 through \$7.50, \$7.51 through \$8.50, etc. up to charges over \$10.50 for 6,000 gal. Customers under schedules charging \$5.50 or less (for which there is no dummy) thus become the bench mark for comparisons. The model is specified in additive form so that coefficients may be read in gallons and compared directly with prices. The results are presented in Table 5.

These results can be converted into a demand curve by calculating the consumption at each price level, as follows:

(coefficient for annual use per person x average number of occupants) +(coefficient for income x average income) + the constant = total consumption

For example, at \$5 (the approximate average bill for the lowest price schedules):

$$(850 \times 3) + (137 \times 12.3) + 2802 = 7{,}065 \text{ gal}$$

At the average price of \$6, all else equal, the customer consumes 6,352 gal (since 731 fewer gallons are consumed at rates between \$5.51 and \$6.50). Another drop in quantity taken is observed at the next higher price range, but the expected price-quantity relationship does not hold for the higher prices.

The null hypothesis that the coefficients of variables D_1 through D_6 are all equal to a common value is not rejected. The common value, however, is significantly less than zero, which implies that additional water is consumed at the lowest prices. Further confirmation came from splitting the data into households with rates above \$8 per 6,000 gal and those below. In the low price group, regressions similar to those in Table 4 produced price elasticity estimates from -0.27 to -0.47. No significant price elasticities could be obtained in the higher price range.

The analysis provides insights into the nature of price impacts that might be anticipated in response to rate increases. At very low rates, some customers behave as if faced by a flat rate schedule, and at higher rates, conservation probably stems from the general recognition that the bill will be less if less water is used. The amount of the price differential does not appear to be important.

TABLE 5. PROFILE OF WATER USE DIFFERENTIAL UNDER VARIOUS RATE STRUCTURES

Dependent Variable	$5.50 to $6.00	$6.51 to $7.50	$7.51 to $8.50	$8.[illegible]	[illegible] to $10.50	Over $10.50	No. occupants per household	Income ($1,000)	Constant	R^2
Average annual use	-7.13	-1296	[illegible]	-1123	-1715	- 898	850	137	2802	0.31
	(-1.73)	(-2.75)	[illegible]	(-2.77)	(-3.19)	(-1.94)	(12.15)	(10.10)		
Monthly summer use	-544	[illegible]	- 928	-1246	-1703	- 769	895	168	2276	.28
	(-1.1[illegible]	[illegible]	(-1.58)	(-2.58)	(-2.67)	(-1.40)	(10.76)	(10.39)		
Monthly winter use	-948	-1225	-1230	-952	-1731	-1079	788	95	2839	.30
	(-2.70)	(-3.04)	(-2.92)	(-2.75)	(-3.77)	(-2.78)	(3.19)	(8.16)		

Validity of the Elasticity Estimates

The emphasis of the analysis above is on policy application; the results also show that the price elasticity estimate of -0.2 is reasonably accurate and, conversely, that estimates of -0.4 to -0.8 are too high.

To check the validity of the formal estimates in Table 4, independently of the technical considerations in defining variables or regression models, simply observe the relatively large percentage differences in rates relative to the small differences in consumption levels.

Consider, for example, the difference in use between the customer with the highest and lowest rates, derived from dividing the data set for the analysis above. Averages for monthly use per household for the three periods are shown in Table 6. These data tend to confirm the low price elasticity estimates and clearly show the upward bias of estimates made with misspecified price variables.

Income Elasticity and Other Determinants of Water Consumption

The details of how income influences consumption, which underlie the general description provided by the elasticity estimate of +0.3, are also of interest for policy decisions. Dummy specifications for income groups were used to estimate the income consumption relationship, with occupants and prices constant. Regression results are shown in Table 7, where the differences in consumption among income groups are representative of results obtained with alternative dummy specifications. A nearly linear increase in consumption is shown up to middle incomes, where increases level off for the upper-middle group and become exponential in the highest income range. Few customers fall in the exponential range of the curve, however.

These estimates are consistent with conventional elasticity estimates for customers with incomes over $20,000, where the income elasticity was found to be in the range 0.4 to 0.6 and no significant price elasticities were obtained. For incomes below $20,000, however, price and income elasticities of -0.2 and +0.2 were highly significant.

Similar use was made of dummy variables to test for significant differences in water consumption associated with urban-rural, metropolitan-suburban, climatic, and other factors. The study area offers some variation in moisture conditions (arid versus humid), but no influence on total water consumption could be attributed to the difference between subtropical and semimountainous areas. There were some differences in the use patterns by months, however. Some density variables were significant, but the differentials in use that were indicated by these tests were negligible. Urban use was not significantly different from suburban or rural use in comparable housing units.

TABLE 6. AVERAGE MONTHLY WATER USE PER HOUSEHOLD (GAL/MONTH)

Period	Above $8/6,000 gal (N = 399)		Below $8/6,000 gal (N = 369)	
	Mean	Std. Dev. of Mean	Mean	Std. Dev. of Mean
Annual	5,929	198	6,201	175
Summer	6,395	235	6,745	200
Winter	5,276	162	5,426	156

TABLE 7. WATER CONSUMPTION ACCORDING TO INCOME CATEGORY

Dependent Variable	Income category: $6,000+ to $10,000	$10,000 to $20,000	$20,000 to $30,000	$30,000 to $40,000	$40,000 or more	No. of occupants in household	Average cost of 6,000 gal	Constant	R^2
Average annual use									
gallons	787	1409	2934	3092	6316	854	- 587	3203	.30
t-value*	(2.40)	(4.72)	(7.98)	(3.82)	(7.10)	(12.06)	(-2.35)		
Monthly summer use									
gallons	923	1686	3537	3645	7999	896	- 705	3359	.28
t-value	(2.37)	(4.76)	(8.10)	(3.79)	(7.57)	(10.66)	(-2.03)		
Monthly winter use									
gallons	596	1022	2090	2319	3958	795	- 661	2983	.29
t-value	(2.13)	(4.01)	(6.64)	(3.35)	(5.20)	(13.13)	(-2.65)		

*The t-value indicates the level of significance of the variables.

CONCLUSIONS

Estimates of the price elasticity for water in the study area indicate that water consumption is relatively insensitive to the price except for conservation induced by the knowledge that a price must be paid. Most previous studies have apparently overestimated the elasticity by misspecifying the price variable. Some have apparently underestimated the elasticity by failing to identify the appropriate price variable. These possible errors have been verified by comparisons of models and variables deliberately misspecified with our corrected models and variables. Our results are strongly supported by direct comparisons of subsets of the data that indicate price/quantity relationships independent of the specification technicalities of the econometric estimates.

The limitations of the price specifications used are inherent in the nature of block rates and are not necessarily more severe than limitations in income measurements or general shortcomings of most data sets. Elasticities suitable for forecasts of high accuracy would require system-specific data; our estimate of a price elasticity of about -0.2 is no more than a descriptive indicator of what might be found in a specific market area.

Within the overall range of price elasticity, the price effect is greater at lower prices and lower incomes. There is no evidence that the price elasticity of water for sprinkling is greater than that of water for other uses, but summer demand is more sensitive to income.

Some policy implications of these findings are that higher price would not be an effective approach to short-run conservation, or, conversely, that increased rates to finance the upgrading of water of sewer systems would only slightly reduce consumption and not interfere with collecting adequate revenues. The analysis raises doubts that stricter Federal regulations of water quality would necessarily have to be offset with Federal grants. In addition, low elasticities imply that water fees might be used as a source of additional municipal revenues.

SECTION 5

APPLIANCES AND OTHER DETERMINANTS OF WATER DEMAND

This section adds descriptive details to the demand determinants discussed in Section 4 and considers the policy implications of these findings. Given the conclusion that the price elasticity for water is quite low and the deduction that demand for irrigation use is no more elastic than the demand for other uses, it appears that pricing policy should be based primarily on revenue considerations and that conservation policies will require maximum-use targets and incentives to stay within the limits established.* Descriptive patterns of residential water use can serve as a basis for establishing targets consistent with the conservation desired.

The following discussion tabulates water usage and selected family characteristics for subgroups of the population based on the most important determinants of consumption--the number of occupants and income. A similar set of profiles based on ownership of water-using appliances is also developed for an analysis of outside summer use for irrigation and other needs.

CUSTOMER AND WATER USE PROFILES

Tables 8 through 11 reveal the interrelationships of the number of household occupants and income in determining the demand for water. They also introduce other factors (such as irrigation practices), that contribute to demand. The patterns of water use, but not necessarily the amounts, are probably typical of those that would be found in any water system. Table 8 shows a descriptive tabulation such as might be undertaken by even a small utility conducting a background study for policy decisions.

Several points are apparent from these tabulations. A dominant factor in determining water consumption is the number of occupants per unit. Within the profiles, it can be seen that average monthly water consumption in the summer is more than 20 percent greater than that for the average winter months and that the peak load for monthly water use is some 50 percent higher

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*Actual policies for ongoing as well as temporary conservation measures might well be patterned after the California experimert described in Consumer Reports (1978). The results reported in this chapter suggest how targets might be established and which conservation practices would contribute most to meeting the targets.

than that during low-use months. The peak load for a hot, dry week is probably considerably higher in most systems.

In more detailed breakdowns not shown in this chapter, a wide range was found between the first and third quartiles, such as those illustrated in Table 8. The gap increased slightly when customers were grouped by income as opposed to the number of household occupants. But even comparisons of consumption by groups with similar incomes and the same number of occupants do not change the pattern of dispersion. The findings give support to conclusions in previous studies that water-efficient appliances could be used to achieve conservation with little or no reduction in the function served by water use.

Table 9 supplies a breakdown of the economic characteristics of customers grouped by number of household occupants. One-person households consist largely of retired individuals with low to moderate incomes. Age and income and number of occupants are the major factors which explain consumption. Within the two lower income categories, a distinction is made between retired homeowners and others, since the nominal retirement income tends to understate the real income of the retired. Income increases with the number of occupants up to four and drops for households with more than five occupants. The drop occurs primarily because the percentage of poor increases with family size, but they replace middle rather than high-income families.

In Table 10, the sample is disaggregated by income groups. Monthly and seasonal averages and the extra use per category are calculated as in Table 8. In addition, Table 10 includes the percent of customers in each group with extra summer consumption over 10,000 gal. This measure was used as a proxy for households with moderately high to heavy irrigation demand. (The proxy was tested in the local data set and found to be an accurate indicator of the use of water for irrigation purposes. The amount of extra, however, includes all extra summer use and is considerably higher than the amount for irrigation alone.)

Comparisons of high- and low-use months, winter and summer use levels, and the amount of extra use show a clear relationship between incomes and extra use. The percent of households with high lawn irrigation demand also increases. Of equal interest, however, is that winter use also increases with income; furthermore, a large percentage of higher-income units do not use great amounts of water for lawn irrigation, and a fairly large number of lower-income groups do irrigate substantially. The importance of these patterns are further discussed below, but the reasons are partially apparent in Table 11, where additional characteristics of each groups are presented.

The relatively low use of retired homeowners compared with others of similar income but fewer assets (Table 10) is partly explained by the lower average number of occupants per household (Table 11). The effect of greater assets is partially evident in the size of dwelling and appliance ownership, but regression analysis shows that any increase in water consumption as a result of high income is offset by reduced consumption at retirement age. Finally, the percent of customers with moderate to heavy lawn irrigation demands (Table 10) is influenced almost as much by type of dwelling (Table 11)

TABLE 8. AVERAGE (MEAN) WATER USE OF CUSTOMERS IN ALABAMA BY NUMBER OF HOUSEHOLD OCCUPANTS

Type of water use	Number of household occupants					
	1	2	3	4	5	6
Monthly water use (gal):						
July 77	4692	6255	7179	10130	10732	12736
Aug. 77	3305	5680	7424	8228	9519	9614
Sept. 77	3670	5942	7330	9013	10141	10411
Oct. 77	3551	4893	5945	7483	7801	9640
Nov. 77	2996	4609	5758	7079	7600	9018
Dec. 77	3161	4560	5708	6926	7541	8569
Jan. 78	3563	5474	6191	6939	9092	9255
Feb. 78	3510	4751	4515	6678	7791	8831
March 78	2933	4493	5476	6654	7029	8131
April 78	3873	5787	6619	8558	9253	10206
May 78	4069	5175	6241	8127	8457	8994
June 78	3797	6078	7051	8994	10576	10788
Total	42823	63707	76537	95805	105528	116193
Average monthly water use (gal):						
Annual	3569	5309	6378	7983	8794	9683
Winter	3173	4779	5750	7055	7811	8761
Summer	3851	5687	6827	8647	9492	10341
Extra water use during the summer season (gal)*:	4747	6359	7537	11145	11796	11061

(continued)

TABLE 8 (continued)

Type of water use	Number of household occupants					
	1	2	3	4	5	6
Daily water use (gal/person):						
Winter months:						
Mean	105	77	62	57	50	41
Median	84	65	61	53	44	41
1st quartile	58	45	45	39	35	30
3rd quartile	115	94	80	71	63	57
Annual:						
1st quartile	70	52	48	43	39	31
Median	97	77	70	61	55	58
3rd quartile	140	113	84	81	73	92

*Extra is the difference between annual use and twelve times the winter monthly average. Winter is November through March. Summer is defined here as April through October; but for a specific system, the irrigation season may differ.

TABLE 9. PROFILES OF WATER CUSTOMERS IN ALABAMA BY ECONOMIC STATUS AND OF HOUSEHOLD OCCUPANTS

Economic status	Number of household occupants						As percent of total
	1	2	3	4	5	6+	
Percent of customers by 1976 income category:							
$0 to $6,000, retired homeowners	35.2	14.2	3.7	1.3	3.8	0.0	11.1
$0 to $6,000, other*	22.1	10.9	10.6	10.5	19.2	21.5	13.9
$6,000 to $10,000, retired homeowners	14.8	11.3	3.7	2.0	0.0	0.0	7.0
$6,000 to $10,000, other*	13.1	12.4	19.3	10.5	11.5	20.0	14.0
$10,000 to $20,000	9.0	29.1	32.9	39.5	44.2	30.8	29.8
$20,000 to $30,000	3.3	12.0	14.3	20.4	13.5	10.8	12.7
$30,000 to $40,000	0.0	2.9	2.5	2.0	3.8	6.2	2.5
Over $40,000	0.0	1.5	0.6	2.0	1.9	1.5	1.2
No answer	4.9	6.5	17.4	12.5	1.9	1.5	9.8
Average income	$6,795	$12,281	$13,298	$16,041	$13,173	$13,858	$12,514
Percent of customers by 1976 employment status:							
Head of household employed	36.9	56.4	80.1	85.5	80.8	84.6	67.1
Head of household unemployed	9.0	5.5	8.1	6.6	9.6	15.4	7.7
Head of household retired	54.1	38.2	11.8	7.9	9.6	0.0	25.0
Spouse employed full time	0.0	23.6	34.2	23.7	25.0	26.2	22.5
Spouse employed part time	0.0	4.4	3.1	5.9	3.8	4.6	3.7
Homemaker--not employed	0.0	56.4	46.6	60.5	63.5	55.4	47.2
Other adults employed full time	0.0	3.6	9.9	4.6	5.8	15.4	5.6
Other adults employed part time	0.0	1.5	0.6	1.3	1.9	4.6	1.3
Other adults employed	0.0	2.5	9.9	3.9	7.7	23.1	5.8
Other adults retired	0.0	4.0	5.6	2.0	1.9	6.2	3.5

*Other than a retired homeowner. The retired homeowner is presumed to have wealth that may influence consumption.

TABLE 10. AVERAGE WATER USE OF CUSTOMERS IN ALABAMA BY FAMILY INCOME

Type of water use	Income Category			
	Other* ($0 to $6,000)	Retired homeowner ($0 to $6,000)	Other* ($6,000 to $10,000)	Retired homeowner ($6,000 to $10,000)
Monthly water use (gal):				
July 77	5975	4344	7423	4759
Aug. 77	4995	3822	6569	4667
Sept. 77	5719	4027	7201	4379
Oct. 77	4965	3561	5922	3726
Nov. 77	4700	3316	4377	3765
Dec. 77	4858	3323	5426	4190
Jan. 78	5685	3695	6145	4648
Feb. 78	5286	3407	5429	4185
March 78	4446	3389	5285	3735
April 78	4848	3800	6527	4256
May 78	4774	3891	6636	3854
June 78	5452	4005	6986	4325
Total	61703	44580	74926	50499
Average monthly water use (gal):				
Annual	5142	3715	6244	4208
Winter	4995	3426	5532	4105
Summer	5247	3921	6752	4282
Extra water use during the summer season (gal):	1763	3468	8542	1239
Daily winter water use (gal/person):	53	66	58	68
Percent of units with extra summer use:				
Greater than 20,000 gal	2.6	4.3	12.9	3.4
10,000 to 20,000 gal	14.8	15.2	16.4	19.0

(continued)

TABLE 10 (continued)

Type of water use	Income category			
	$10,000 to $20,000	$20,000 to $30,000	$30,000 to $40,000	$40,000+
Monthly water use (gal):				
July 77	7863	10902	11491	20922
Aug. 77	7276	8776	10335	11683
Sept. 77	7302	10004	9347	12260
Oct. 77	6489	7430	7323	10986
Nov. 77	6001	7362	6439	10201
Dec. 77	5930	6835	6708	8890
Jan. 78	6736	7736	8108	11795
Feb. 78	5963	6778	6499	10118
March 78	5346	6469	6780	8917
April 78	7279	9205	10666	13546
May 78	6568	7798	8660	16270
June 78	7815	9431	11462	14735
Total	80968	98726	103818	150323
Average monthly water use (gal):				
Annual	6749	8227	8652	12257
Winter	6075	7036	6907	9984
Summer	7227	9078	9898	14343
Extra water use udring the summer season (gal):	8068	14294	20934	30515
Daily winter water use (gal/person):	58	70	62	95
Percent of units with extra summer use:				
Greater than 20,000 gal	15.1	25.4	47.6	50.0
10,000 to 20,000 gal	18.0	25.4	19.0	18.7

*Other than a retired homeowner, who is assumed to lease assets that may influence consumption.

and home ownership (Table 11) as by income. For example, single family homeowners in the lowest income/asset category would have about the same percent of moderately heavy waterers as the middle-income group.

An assessment of how appliance ownership and lawn irrigation contribute to the system load is begun with data provided by profiles in Table 12. Before evaluating the content of the table, however, it is useful to review what cannot be found from these data. The approach used in Table 12 was proposed and tested by Batchelor (1975). This investigator first ranked water-using appliances in order, from the most frequently owned to the least frequently owned. He then grouped households by ownership of appliances--all appliances, all but the least frequently owned, all but the two least frequently owned, etc. Batchelor then subtracted the average consumption of the second group from that of the first group to estimate the water used by the appliance least frequently owned. For example, if in the first two columns of Table 12, annual water use of about 110,000 gal for households with dishwashers and washers is subtracted from the annual use of about 138,000 gal for households with garbage disposals as well, the resulting 28,000 gal is the theoretical annual estimate of water used by a garbage disposal. (An estimate of 19,000 gal is produced by using the same procedure for the fourth and fifth columns.)

Batchelor found his method of estimating appliance use unsuccessful, however, because the hierarchy of appliances tends to measure income and therefore overstates the water use of the less frequently owned appliances. The average incomes shown in Table 12 and the estimates of water use by garbage disposals above confirm the limitation noted by Batchelor, but they also suggest that the appliances owned reflect characteristics other than income that contribute to water consumption. Greater water consumption is associated with the user's lifestyle (as reflected in the greater mobility and newer housing of heavy water users) and life cycle (as reflected in the fewer occupants and greater ages of those using less water).

Table 12 contains an important modification of Batchelor's approach, since the ownership of lawn sprinklers (or more precisely, their use) is removed from the hierarchy of appliances owned. As noted above, a greater percentage of lawn sprinklers is found at higher incomes, but they are scattered over the population, whether ranked by occupant's income or other characteristics such as age of occupants or type of housing unit. Thus the income bias associated with the use of lawn sprinklers is reduced (although not entirely eliminated) when comparing the water use of customers who do moderate to heavy sprinkling with that of customers who do little to no sprinkling. Comparisons of annual water use therefore provide rough indicators of the maximum amounts of water use for lawn irrigation. The estimates range from 35,000 to 48,000 gal per year for heavy lawn waterers.

The upward bias of these estimates is revealed by the calculation of extra summer use shown in each column. These indicators show that moderate to heavy lawn waterers probably use no more than 26,000 to 34,000 gal for all extra summer needs. In addition, comparison of monthly use levels in winter months show that the heavy irrigators also use considerably more water than the non-sprinklers for other purposes. We thus conclude that the value of

TABLE 11. PROFILES OF WATER CUSTOMERS IN ALABAMA BY HOUSEHOLD CHARACTERISTICS AND FAMILY INCOME

Household characteristic	Income category							
	Retired homeowners ($0 to $6,000)	Other* ($0 to $6,000)	Retired homeowners ($6,000 to $10,000)	Other* ($6,000 to $10,000)	$10,000 to $20,000	$20,000 to $30,000	$30,000 to $40,000	$40,000+
Average occupants per household	1.71	3.04	1.90	3.06	3.88	3.29	3.52	3.44
Average square footage of home	1157	995	1501	1131	1542	1964	2431	2900
Percent of units with:								
Dishwasher	7.6	3.5	29.3	13.8	44.4	81.7	90.5	87.5
Food disposal	0.0	0.9	5.2	4.3	11.6	34.1	57.1	56.2
Clothes washer	77.2	50.4	86.2	80.2	92.2	98.4	95.2	100.0
Water heater	93.2	92.2	98.3	98.3	99.6	100.0	100.0	100.0
Type of dwelling (percent):								
Single family	95.7	70.4	98.3	83.6	93.7	98.4	95.2	100.0
Duplex	1.1	14.8	0.0	4.3	1.4	0.0	0.0	0.0
Apartment	1.1	9.6	0.0	8.6	2.5	0.8	4.8	0.0
Mobile home	2.2	5.2	1.7	3.4	2.5	0.8	0.0	0.0
Homeowners (percent)	100.0	40.9	100.0	67.2	88.0	97.6	90.5	100.0
Employment status (percent):								
Head of household employed	0.0	50.4	0.0	92.2	85.6	92.1	95.2	75.0
Head of household unemployed	10.9	30.4	3.4	6.0	3.2	0.8	0.0	0.0
Head of household retired	89.1	18.3	96.7	1.7	11.3	7.1	4.8	25.0
Spouse employed full time	1.1	8.7	6.9	23.3	31.0	39.7	19.0	12.5
Spouse employed part time	1.1	0.9	0.0	4.3	4.9	7.1	4.8	0.0
Homemakers--not employed	33.7	35.7	56.9	46.6	51.1	46.8	76.2	75.0
Other adults employed full time	3.3	5.2	8.6	6.0	4.6	5.6	14.3	12.5
Other adults employed part time	2.2	2.6	1.7	1.7	0.7	0.8	0.0	0.0
Other adults unemployed	5.4	10.4	1.7	7.8	4.9	4.8	4.8	0.0
Other adults retired	8.7	3.5	3.4	2.6	3.5	1.6	1.6	0.0

*Other than a retired homeowner, who is assumed to have assets that may influence consumption.

TABLE 12. WATER USE PROFILES OF ALABAMA WATER CUSTOMERS BY LAWN SPRINKLING HABITS AND APPLIANCE OWNERSHIP

Customer characteristics	Customers practicing moderate to heavy springling			Customers practicing little or no sprinkling			
	With disposal, dishwasher, and washer	With dishwasher and washer	With washer	With disposal, dishwasher, and washer	With dishwasher and washer	With washer	With no washer
Age of head of household	47	48	52	48	49	52	55
Year moved in	1970	1968	1964	1967	1964	1963	1964
Year home built	1965	1958	1951	1958	1955	1951	1943
Square footage of home	2,355	1,968	1,373	2,088	1,703	1,282	985
Number of residents per household	3.64	2.76	3.39	3.23	3.09	2.94	2.53
Average 1976 income	$24,576	$20,245	$11,500	$21,008	$15,879	$ 9,306	$ 4,870
Water use (gal):							
July 1977	17,655	14,112	12,301	9,236	6,123	6,123	4,674
August 1977	12,427	11,488	9,863	7,379	6,018	5,591	4,034
September 1977	13,074	11,326	10,939	8,124	6,567	5,677	4,576
October 1977	9,373	8,364	7,349	7,450	5,661	5,212	4,094
November 1977	8,865	7,088	5,986	7,645	5,570	5,006	3,782
December 1977	8,268	6,957	5,780	7,154	5,581	5,093	3,893
January 1978	10,026	7,766	5,993	8,383	6,346	5,836	4,674
February 1978	8,091	6,566	5,413	7,642	5,637	5,231	4,213
March 1978	8,015	6,629	6,000	6,952	5,198	4,835	3,837
April 1978	14,316	9,812	9,118	8,073	6,465	5,441	4,336
May 1978	12,910	8,974	9,762	6,783	5,667	5,103	3,944
June 1978	15,193	11,168	11,063	7,326	6,101	5,661	4,575
Annual water use (gal)	138,213	110,250	99,567	90,149	71,254	64,811	50,632
Monthly average winter use (gal)	8,653	7,001	5,834	7,555	5,666	5,200	4,079
Monthly average summer use (gal)	13,564	10,749	10,056	7,767	6,131	5,544	4,319
Extra use, summer season (gal)	34,377	26,236	29,554	1,484	3,255	2,401	1,673
Daily winter use (gal/person)	79	85	57	78	61	59	54
Daily summer use (gal/person)	124	130	99	80	66	63	57
Difference (gal/person)	45	45	42	2	5	4	3
Percent of customers	5.1	7.0	7.4	6.4	17.0	40.7	13.6

Batchelor's appliance grouping lies in the identification of more or less homogeneous groups of customers rather than in providing a methodology for estimating water use by appliance.*

USE OF REGRESSION ANALYSIS TO ESTIMATE WATER USE BY APPLIANCE

An alternative method for estimating the water used by various appliances is to specify the appliances and independent variables in a regression analysis explaining water consumption. Ideally, every use of water would be associated with an appliance such as a sprinkler or toilet. As a practical matter, the number of occupants serves as a proxy for the group of appliances such as toilets present in almost all housing units. Income is used as the regressor to explain the intensity of appliance use in general. Though the general limitations of this alternative method of estimating the amount of water consumed by specific appliances are almost as severe as the limitations of the profile method used above, they are different and the two methods are complimentary.

Table 13 gives the results of regression equations using appliances and demographic variables to explain monthly water use for summer and winter, and average annual water use. The coefficient for each of the independent variables is the amount of use per month that can be attributed to the particular characteristic described by the independent variable. The R^2 for the first equation indicates that the age and number of children in the household plus the types of water-using appliances explain about 35 percent of the total variation is use. The dishwasher variable is the only variable that is not significant, which indicates that the presence of a dishwasher gives no additional information about the water-use characteristics of the home. The regression indicates that 643 gal per month can be attributed to an automatic washing machine and 776 gal can be attributed to a garbage disposal. The fact that a customer employs heavy sprinkling in summer indicates an additional 976 gal of use even in the winter.

Equations explaining appliance use in the summer and annually have similar interpretations. As in the profile analysis, the 787 gal per month of annual use associated with a garbage disposal must reflect the surrogate relationship of this variable to income and lifestyle. For our purposes, however, we note that whatever the proxy relationship may be, it explains a constant factor over the year (the difference in summer and winter use amounts to only 17 gal), so we presume that the presence of garbage disposals does not identify lawn waterers. The use associated with clothes washers and dishwashers is at least in a comparable range with studies that have estimated water use by functions. But over all, these estimates of water use by

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*The concept is nevertheless a substantial contribution to utility demand analysis. Unfortunately, the major water-using appliances are toilets, tubs or showers, and sinks, which cannot be included in the analysis because they are present in virtually all residences served by water systems. In the analysis of energy demand, the most important appliances can be segmented into customer groupings, and the hierarchy problem can be more successfully avoided.

TABLE 13. WATER USE ESTIMATED DERIVED FROM REGRESSION ANALYSES USING APPLIANCE OWNERSHIP AND DEMOGRAPHIC VARIABLES

Dependent variable	Independent variable					
	No. of persons/household			Appliance ownership		
	Pre-school or elementary children	teen-agers	Adults other than head of household	Automatic clother washer	Garbage disposal	Dish-washer
Monthly winter use:						
gallons	269	1102	813	643	776	200
t value†	(2.50)*	(9.90)	(5.57)	(2.59)	(2.39)	(.83)
Monthly summer use:						
gallons	312	1141	906	424	793	120
t value	(2.34)	(8.27)	(5.01)	(1.38)	(1.97)	(.40)
Average annual use:						
gallons	294	1125	867	516	787	153
t value	(2.50)	(9.24)	(5.44)	(1.89)	(2.21)	(.58)

(continued)

TABLE 13. (continued)

Dependent variable	Independent Variable						
		Age of head of household					
	Moderate to heavy sprinkling	55 to 61	62 to 64	65 and over	Total family income ($1000)	Constant	R^2
Monthly winter use: gallons	976	-698	-1006	-831	41	2905	0.35
t value†	(4.05)	(-2.40)	(-2.44)	(-3.15)	(2.86)		
Monthly summer use: gallons	4651	-1033	-1346	-936	75	3160	0.47
t value	(15.59)	(-2.87)	(-2.63)	(-2.86)	(4.25)		
Average annual use: gallons	3120	-894	-1204	-892	60	3054	0.44
t value	(11.35)	(-2.81)	(-2.67)	(-3.90)	(3.90)		

*Derived by checking whether the customer used more than 5,000 gal more than the average winter use during any single summer month and more than 10,000 gal extra during the entire summer

†The t value indicates the level of significance of the variable

appliance (other than the sprinkler, which is discussed below) contribute little to an understanding of water consumption, because 70 to 80 percent of water use occurs in the bathroom (see Kim and McCune, 1977).

The pattern of use by age of occupant is of greater interest. Teenagers account for a greater use than adults or younger children. Water use declines as the head of the household ages, a trend that slows somewhat in retirement years. This apparent quirk is explained in the following section.

The moderate to heavy lawn waterer variable provides useful insights into irrigation demand. The monthly summer use of 4,651 gal is equivalent to 33,000 gal for the season and is consistent with the estimate obtained in comparing profiles. Since for each winter month these customers use 976 gal more than the average, we can assume that nonirrigation use during the summer is at least as high, which would leave an average extra summer demand for irrigation of no greater than 25,000 gal.

Table 14 gives the results of two of several attempts to pinpoint the demand for irrigation needs using the local survey data. Conceptually, the model is specified so that each household is classified by number of occupants and lawn-watering habits (waterers and nonwaterers), according to the questionnaire response. Thus the first nine variables are dummies for all customers except the two-occupant households that water a lawn or garden. (It is necessary to leave out one category when using dummy variables.) Variables 10 through 13 are dummies for each income class except $10,000 to $20,000. In step 1 of the regression explaining annual use, subtracting variable 1 from variable 6 provides the implicit demand of 20,000 gal for irrigation by the one-occupant household that waters. Similarly, variable 2 indicates that two people who never water use 10,248 gal less per year than two people who water--an amount represented by the constant. Low t values and illogical results for three people preclude the use of this estimating scheme; but some of the general implication of the results from this regression were supported by other regressions.

The final step, with all the insignificant variables deleted, shows households with four or more occupants that irrigate and households with incomes greater than $30,000 as the only groups using significantly more water than average, and it shows households headed by those past retirement age as the only group using less water than the average. An alternative interpretation is that variations in water use among units with three or fewer occupants are so great for both watering and other uses that identifying the type of use does not increase the predictability of total use. The picture unfolds as the insignificant income coefficients in step 1 and the final step of a regression explaining only the extra summer use are considered.

The fact that variable 10 is positive in the third column implies that the lowest income groups use more than those with incomes between $10,000 and $20,000. (Since the $10,000 to $20,000 income group is the dummy variable left out of the regression equation, all coefficients are relative to use in the $10,000 to $20,000 income group.) In the final step (summer extra use), variable 14 is no longer significant, but one-occupant households that are

TABLE 14. REGRESSION ANALYSIS OF DEMAND FOR LAWN IRRIGATION WATER, TUSCALOOSA, ALABAMA*

Variable no. and description	Mean (%)	First step, annual use		First step, annual use		Final step, Summer Extra Use	
		Coefficient (gal)	t value	Coefficient (gal)	t value	Coefficient (gal)	t value
Nonwaterers:							
1. 1 occupant	4.2	- 6,747	-0.32	------	----	------	----
2. 2 occupants	11.9	-10,248	- .75	------	----	------	----
3. 3 occupants	3.4	17,234	.76	------	----	------	----
4. 4 occupants	6.8	20,230	1.21	------	----	------	----
5. 5+ occupants	4.2	16,884	.83	------	----	------	----
Occasional waterers:							
6. 1 occupant	6.8	13,065	.75	------	----	39,919	2.19
7. 3 occupants	10.2	6,158	.43	------	----	------	----
8. 4 occupants	16.1	27,442	2.15	22,714	2.09	------	----
9. 5+ occupants	10.2	45,940	2.89	38,815	2.72	------	----
Income:							
10. $0 to $10,000	33.9	12,684	1.14	------	----	------	----
11. $20,000 to $30,000	16.1	755	.06	------	----	------	----
12. $30,000 to $40,000	5.9	65,475	3.79	60,511	3.76	60,099	3.10
13. $40,000	7.6	51,538	3.03	51,991	3.27	80,849	4.69
Age:							
14. Aged 65 or over	23.7	-21,489	-1.88	-15,756	-1.68	------	----
Constant		66,695	------	74,189	----	14,247	----
R^2		-------	.39	------	.36	------	.22

*Number of samples is 118.

waterers use up to 54,000 extra gal per summer (constant plus the coefficient for variable 6). The apparent contradictions leave little doubt that one-occupant households are a diverse group with a wide range of lifestyles and water consumption characteristics. The group contains a large percentage of retired individuals, and most of these have minimal demands for water because of reduced activity or time spent away from home. For some, however, the yard or garden becomes a recreation, and the amount of water used for irrigation is much greater than for the typical household. Differences within this group are more extreme, but they are not fundamentally different from the diverse use patterns resulting from lifestyle variations among households of other groups.

FURTHER ANALYSES OF WATER USE FACTORS

Through a more detailed examination of profiles and extensive use of regressions, an effort was made to find factors other than those already noted that might significantly influence water consumption. In general, other factors influencing consumption were insignificant, small, or indirectly related to the number and age of occupants or income. For example, the age and size of the housing unit, lot size, amount of lawn irrigated, type of neighborhood, and population density were all rejected as independent determinants of water use. Assessed property values (a variable often used as a proxy for income) proved to be a better predictor of water use than income, since it reflects both income and the way it is used. Information on car washing did not prove to increase significantly the explanatory power of the model.

The combined analysis of profiles and regressions was also used to add details to the general outline of demand for irrigation water. The sample was split into high and low users within each of the appliance categories (Table 12). From the regression analysis in Table 13, we assume that only about 80 percent of the extra summer use of heavy irrigators is for lawn irrigation, swimming pools, water-cooled air conditioners, and other outside needs. Within the 20 percent of the population assumed to be heavy lawn waterers, the top half consumes about 10,000 gal for irrigation in a peak month, and about 45,000 gal for all extra summer needs. The bottom half of the heavy irrigators averages about 6,500 gal of extra use in a peak month, but less than 20,000 for irrigation during the entire summer. The extra summer use within both groups is roughly proportional to their total water consumption; both groups use about 20 percent of their total consumption for irrigation, and summer extra use is about 25 percent of the total.

From the local survey, we assume that of the remaining 80 percent of water customers, about half use more than negligible amounts for irrigation. Regression analysis of the statewide sample indicates that the more modest irrigators average about 5,000 gal per season for irrigation, plus another 1,000 to 3,000 of extra use in the summer for non-irrigation purposes. The range, especially for occupant-induced consumption, is quite wide and depends on the ages of children and adults. The last 40 percent includes some large users with winter peaks and non-irrigators (or light sprinklers) that have extra summer needs of only 2 or 3 percent of their total requirements. Overall, about 15 percent of the customers account for 60 percent of extra summer

use, and half of the customers contribute only negligibly to the need for excess capacity during the summer.

The overall estimate of lawn irrigation demand shows that such water accounts for about 9 percent of total use; by contrast, Kim and McCune (1977) report this figure as 3 percent, and Howe and Lineweaver (1967) estimate that it accounts for up to 40 percent in metered areas. Given the relative ease of estimating irrigation demand for specific systems, policies to encourage conservation of water for outside purposes should be based on local data and objectives. Our other findings have greater general applicability. Variations in in-house demand that cannot be traced to occupants, income, or other factors reflect individual differences to a large extent. Our analysis suggests, however, that leaks and inefficient appliances must be responsible for a large amount of the unexplained variations in use among similar households.

Profiles and regression analyses were also used to further examine the possibility of a threshold effect. The burden of the water and sewer bill was calculated as a percent of family income. For the lowest income groups, the water bill averages slightly over 3 percent of income and ranges from 1 to 4 percent. At median incomes, the burden drops below 1 percent, and at higher incomes (where demand is more income elastic), the burden averages less than 0.5 percent. No evidence was found that the impact of the burden is any greater than the almost negligible price effect. On the contrary, inconclusive evidence suggested that the incidence and duration of leaks is most heavy at the lower incomes and that such leaks more than offset the aggregate conservation induced by price and income for the group as a whole.

CONCLUSIONS

The policy implications of the threshold analysis are that direct regulations such as prohibiting irrigation or setting appliance standards would be a more effective inducement to conservation than price increases that will occur from anticipated expansion and improvement of water and sewage facilities. Neither regulations nor normal price increases, however, would be as effective as the relatively high penalty rates imposed under an inverted block rate structure. Appliance standards would have only a gradual impact over an extended period. Bans on irrigation might effectively control temporary peak-load problems, but they would have little effect on the base load requirements. The sudden shock of a substantial rate increase, combined with wide distribution of effective and inexpensive conservation techniques, could be expected to reduce water consumption and sewer loads substantially and quickly if motivation and cost-effective solutions for conservation were provided simultaneously.

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APPENDIX A

ESTIMATES OF CONSUMPTION ASSOCIATED WITH THE OWNERSHIP OF APPLIANCES: A REGRESSION APPROACH

This appendix provides a limited sample of the methodology presented in the text and summarizes the findings from a number of alternative model specifications. The data base for these regressions is from the local survey, and the primary emphasis is on water use for lawn irrigation. In the local survey, detailed data on lawn irrigation practices were obtained. Similar data were not available in the statewide survey. By extending a regression approach tried by Batchelor (1975), an effort was made to estimate the use of water by sprinklers, washing machines, and other appliances. The analysis supplements data presented in the text, and although it is of limited success for the intended purpose, it proves valuable in explaining the interrelationships in life cycles and hetrogeneous lifestyles that make water consumption difficult to forecast.

Table A-1 identifies the importance of irrigation in total water consumption by income groups and the use associated with selected appliances (variables 14 through 16). Variables 9 through 12 are used to hold constant the variation accounted for by the number of household occupants. If we subtract the coefficient for Variable 1 from the coefficient for Variable 5 (14,113-10,745 = 3,368), the difference is an estimate of water associated with lawn sprinkling in households with incomes up to $10,000. The households with incomes between $10,000 and $20,000 that sprinkle have been omitted from the variable list to avoid the multicollinearity problem in the use of the 1-0 dummy variable. So the coefficient for Variable 2 subtracted from zero (i.e., changing the sign) (0-(-10,876) = 10,876) becomes the implicit estimate of irrigation use in this income class. Similarly, the betas for (Variable 6 - Variable 3), etc., generate an array of irrigation use estimates for the several income classes considered.

The results are highly distorted, as would be expected from the low t values of the key irrigation variables; so we skip to Step 8 of our backward elimination regression program. Here, the coefficients provide a clearer picture of irrigation use, and the apparent inconsistencies provide insights into the pattern. Irrigation use is significantly influenced only by incomes over $30,000, and the influence of household occupants on water use emerges in the expected patterns. The large and highly significant negative usage (i.e., deduction from the constant) for households with heads over age 65 is representative of the results from a number of alternative tests of this condition.

TABLE A-1. REGRESSION ANALYSIS OF ANNUAL WATER DEMAND FOR LAWN IRRIGATION AND SELECTED APPLIANCES

Variable No. and brief description	Mean %	Step 1 Coefficient (gal)	Step 1 t Value	Step 8 Coefficient (gal)	Step 8 t Value	Without Appliance Coefficient (gal)	Without Appliance t Value
Nonwaterers:							
1. Income; $0-$10,000	14.4	14,113	1.05	14,414	1.20	-	-
2. Income; $10,000-$20,000	11.9	-10,876	- .09	-	-	-	-
3. Income; $20,000-$30,000	3.4	-15,706	- .73	-	-	-	-
4. Income; $30,000+	.8	16,030	.39	-	-	-	-
Occasional waterers:							
5. Income; $0-$10,000	19.5	10,745	.91	14,674	1.39	-	-
6. Income; $20,000-$30,000	12.7	-19,067	-1.39	-	-	-	-
7. Income; $30,000-$40,000	5.9	42,879	2.48	52,588	3.35	64,552	4.07
8. Income; $40,000+	6.8	41,875	2.39	52,324	3.36	58,497	3.62
9. 1 occupant	11.0	- 1,274	- .08	-	-	-	-
10. 2 occupants	38.1	-18,686	-1.56	14,160	-1.50	-11,814	-1.20
11. 4 occupants	22.9	16,506	1.31	16,617	1.52	15,952	1.40
12. 5+ occupants	14.4	20,739	1.41	24,318	1.86	24,899	1.85
13. Age 65 and over	23.7	-27,435	-2.57	-25,507	2.53	-18,036	-1.92
14. Disposal	17.8	40,321	3.68	9,938	3.87	-	-
15. No clothes washer	11.0	-13,320	-1.28	-	-	-	-
16. Dishwasher	57.6	4,285	.47	-	-	-	-
Constant		79,037		71,299		79,358	
R^2			.47		.45		.37

The unexpected results indicating that the lowest income groups use more water than families in the $10,000 to $30,000 range and that waterers and nonwaterers behave similarly raises several questions as to habits and lifestyles as well as to the efficacy of the model specification. One testable hypothesis raised by the regression is that one-person households on retirement incomes dominate the out-of-line results, with the over-65 variable offsetting the positive low-income variables and the absence of a negative beta for one person. This possibility is followed in the subsequent regressions.

A second question is raised by the performance of the household appliance variables. The implied use of over 13,000 gal of water per year by a washing machine (or in the regression, water not used if there is no washer) is plausible but not significant. The implied use of over 100 gal per day by a disposal appears unreasonable and also suggests that this variable may lead to serious distortions in other results. The matter is resolved by excluding household appliances from the regressor list in a modified specification of the model. The coefficients for Step 8 provide the results, and indicate that the earlier positive coefficient on low income was a distortion.

Table A-2 presents the results of further efforts to trace the patterns and quantify the amount of water used for lawn irrigation. The new list is similar to Table A-1 in concept and design, but now income is held constant, and the implicit amount of water used for irrigation is provided by subtracting the coefficient for Variable 1 from the coefficient for Variable 6, etc. The results, derived from Step 1, are as follows:

Type of Household	Approximate gal/year
1 person	20,000
2 persons	10,000
3 persons	11,000
4 persons	7,000
5+ persons	29,000

The array appears plausible except for the 3-person household. The use explained by income, (variables 10 through 13 in Table A-2) would also appear plausible except for the extra 13,000 gal used by the lowest income group. Although the t values for key variables are small, the results can be interpreted as a best estimate of the average irrigation use in households with widely varying irrigation requirements.

Coefficients from the final step, after all insignificant variables are eliminated, again show that the only dependable forecasting relationship is extra irrigation needs in households occupied by four or more persons and that families with incomes over $30,000 use considerably more water than lower income groups.

TABLE A-2. REGRESSION ANALYSIS OF WATER DEMAND FOR LAWN IRRIGATION

Variable No. and Brief Description	Mean %	Step 1 Annual Coefficient (gal)	Step 1 Annual t Value	Final Step Annual Coefficient (gal)	Final Step Annual t Value	Final Step Summer Extra Coefficient (gal)	Final Step Summer Extra t Value
Nonwaterers:							
1. 1 occupant	4.2	- 6,747	- .32	-	-	-	-
2. 2 occupants	11.9	-10,248	- .75	-	-	-	-
3. 3 occupants	3.4	17,234	.76	-	-	-	-
4. 4 occupants	6.8	20,230	1.21	-	-	-	-
5. 5+ occupants	4.2	16,844	.83	-	-	-	-
Sometimes water with:							
6. 1 occupant	6.8	13,065	.75	-	-	39,919	2.19
7. 3 occupants	10.2	6,158	.43	-	-	-	-
8. 4 occupants	16.1	27,442	2.15	22,714	2.09	-	-
9. 5+ occupants	10.2	45,940	2.89	38,815	2.72	-	-
10. Income; $0-10,000	33.9	12,684	1.14	-	-	-	-
11. Income; $20-30,000	16.1	755	.06	-	-	-	-
12. Income; $30-40,000	5.9	65,475	3.79	60,411	3.76	60,099	3.10
13. Income; $40,000+	7.6	51,538	3.03	51,991	3.27	80,849	4.69
14. Age 65 and over	23.7	-21,489	-1.88	-15,756	-1.68	-	-
Constant	-	66,695		74,189		14,247	
R^2	-		.39		.36		.22

The distortions uncovered in Table A-1, that the lowest income group and one-person households use more water than middle income and two- or three-person households is generally supported by Step 1 of Table A-2. The general implication, however, is that a single-occupant household tends to water much more than the average.* This implication is born out in a modification of the regression.

A direct attack on estimating the water used for irrigation is provided by a regression explaining the extra summer consumption. "Extra" was defined as the excess use during the summer irrigation period over the base use as established during the winter months.† Extra use was used as the dependent variable with an identical list of regressions. The last step of this model specification is shown in Table A-2. The single-person household that waters emerges as a highly significant factor, along with higher income groups; and the age of the head of household is a negligible and insignificant factor that is dropped out of the variable list.

Taken together, the results in Tables A-1 and A-2 supplemented with similar model specifications leave little doubt that the one-occupant household is a diverse group with a wide range of lifestyles and water consumption characteristics. For some, water use may be minimal because of reduced activity and needs in the retirement years, or because of time spent away from home. For others, the yard or garden becomes a recreation, and the proportion of water for irrigation is far greater than for a typical household. The differences are more extreme, but these are not fundamentally different from those resulting from lifestyle variations that lead to diverse use patterns among household that are similar in the most reliable predictors, income and occupants.

These differences among groups similarly defined helps to explain the relatively low R^2's in Tables A-1 and A-2. Regardless of the variable included or the combinations of variables tried, we were unable to produce an R^2 above 0.50.

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*Although the details of the analysis will not be presented here, the household with five or more persons is also a special case. Income and number of household occupants are positively correlated, but households with five or more occupants tend to be upper-middle to high income or low income. Since the higher income families with children nearly all irrigate, and since those using water for irrigation also use more water for other purposes, the beta for variable 9 is quite large. But variable 5 is heavily weighted with low incomes.

†Several variations were used to define extra, all with similar results. Here, the total consumption for October through March bills is subtracted from the total April through September. This rough approximation is somewhat distorted by vacation periods, Christmas visitors, and leaks from freezes, but it is less of a problem in the small pilot survey than in the primary data set.

A final factor to be noted in Table A-2 is the constant in the final step (summer extra) relative to the size of the betas. The average extra consumption per household being explained is 27,400 gal (this is the mean of the dependent variable), and the constant implies that 14,247 gal of extra consumption is the average use for all categories not identified. In the categories identified as users of the extra, each accounts for several times the average extra during the summer. The rather large differences lead to further analyses, which are summarized as follows.

Over 75 percent of the population not identified by the significant coefficients (income less than $30,000 and households of two or more persons) are responsible for less than 40 percent of summer extra use. Those who do water use an average of about 20,000 gal during the summer, and the 30 percent who do not water use an extra 4,000 gal for purposes other than irrigation. In the income-related summer use, the average extra is about 85,000 gal per summer.* Within these averages, one-third to one-half of the extra summer use is for human use rather than for lawns and gardens. Among the waterers, the typical household below a $20,000 income (and many of those above) probably uses far less than 10,000 gal per year for irrigation. Typical heavy waterers are found randomly over the income ranges and account for a relatively large amount summer extra use. The use per person, however, is closely tied to income and is higher in both winter and summer.

The major limitation in the above analysis is the relatively small sample size and some distortion in responses obtained from an otherwise random population. The sample is biased toward homeowners and older households, and the lowest income group of working customers is underrepresented. However, a number factors were examined other than those reported above. Those that appear most relevant are summarized as follows.

The use of appliances as regressors, as illustrated by the use of disposals in Table A-1, will typically act as a proxy for income or lifestyle, as found by Batchelor (1975). Though the problem can be circumvented in some model specifications, the variations in the water consumption of an appliance according to the number of household occupants makes the procedure questionable except for a few special analyses.

The use of the assessed value of property as a proxy for family income can always be expected to produce the desired results. Income partially determines the housing unit and lifestyle, which in turn determines water use (along with the other unrelated determinants). The use of assessments is simply going directly to the primary determinant.

The use of data on lot size and frontage is of little value except as they indirectly indicate property value. Small frontage usually indicates lower water use, for example. No relationship was found between the size of lot and the amount of irrigation, however. The same was true for the size and type of garden (vegetable or flower).

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*[(60,099 + 14,247) + (80,849 + 14,247)] ÷ 2 = 84,721

Gardeners use more water for irrigation than lawn waterers, on the average, in both lower and upper income groups. Gardeners are generally concentrated in the lower to middle income ranges and use less water for other purposes. "Watering a garden extensively" did not show up as significant as variable in the list explaining overall water consumption. The age and size of the housing unit is not significantly related to water usage except as these variables indirectly reflect value and income.

APPENDIX B

LOCAL STUDY QUESTIONNAIRE

The questionnaire used in the pilot study was part of an energy use study. Several questions were asked as an aid in a pilot study on water use in Tuscaloosa County, Alabama.

The questionnaire was constructed so that the interviewer would ask for general qualitative information and try to qualify the information or have the interviewee further quantify the information.

WATER USE QUESTIONNAIRE

Card 1

1. Type of residence:
   1. Single Family
   2. Duplex
   3. Apartment
   4. Mobile home
   5. Condominium

2. Do you own or rent your home?
   1. Own
   2. Rent

3. Are utilities included in your rent or are they excluded?
   1. Included
   2. Excluded

4. What year was your home built?
   19__

5. What year did you move in?
   19__

6. Home is served by:
   1. Water, sewer, garbage
   2. No water
   3. Water, no sewer
   4. Water, sewer, no garbage

7. Number of rooms (count a combination living room - dining room as one room unless full size is indicated; do not count baths).

   ____ ____

8. Square feet (sq. ft. of heated and cooled area)

   _____ _____ _____ _____

9. Number of people living in the home.

   _____ _____ Total
   _____ _____ Children under 25

Appliance Saturation

Which of the following appliances do you own?

10. Range?
    0. None
    1. Natural gas
    2. Electric
    3. Bottled fuel
    4. Other fuel

11. Dishwasher?
    0. No
    1. Yes

12. Clothes dryer?
    0. None
    1. Natural Gas
    2. Electric
    3. Other fuel

13. Automatic washer?
    0. No
    1. Yes

14. Freezer?
    0. No
    1. Yes, one unit
    2. Yes, more than one

15. Garbage disposal?
    0. No
    1. Yes

16. Water heater?
    0. None
    1. Natural gas
    2. Electric
    3. Bottled fuel
    4. Other fuel
    5. More than one, using different fuels

    If more than one, specify each use._____

    _____

17. Do you have a swimming pool, water-cooled air conditioner, or anything else requiring large amounts of extra water?
    0. No
    1. Swimming pool
    2. Water-cooled air conditioner
    3. Other (specify) _____

18. Are there any other major energy or water uses besides the appliances mentioned before?
    0. None
    1. Shop
    2. Rental apartment
    3. Other (specify) _____
    4. Swimming pool
    5. Pool heater

19. Determine frequency of use, record the impact of increased use on:
    0. None
    1. Water
    2. Electric
    3. Gas
    4. Water and gas
    5. Water and electricity
    6. Gas and electricity
    7. All

NOTE: Questions 20-32 were concerned with energy use.

33. How often do you wash your car?
    1. Frequently (2 or more times per month)
    2. Ocassionally (6-8 times per year)
    3. Never (or almost never)

34. Do you water your lawn and shrubs?
    0. No
    1. Yes

35. If yes, what percent of your lot is watered?
    ____ ____

36. Do you water a vegetable or flower garden?
    0. No
    1. Yes

    If yes, what size is it?
    1. Very small (10 ft. sq.)
    2. Medium size garden (20-30 ft. sq.)
    3. Large garden (over 30 ft. sq.)

37. How often do you water?
    1. Waters garden frequently (3 times per week)
    2. Waters garden occasionally (once a week)
    3. Only to keep from dying
    4. Never (includes very small amounts and/or almost never)

38. Have you changed your consumption of water in the past five years?
    0. No change
    1. Reduced use, change in lifestyle
    2. Increase use, change in lifestyle
    3. Reduce use because of increased cost
    5. 1 and 3
    7. 2 and 3
    9. Other

39. Do you know the amount of your water bill? (ask the amount)
    0. Does not know or is vague about the amount of the bill
    1. Knows amount of bill vaguely, not the difference in high and low low months
    2. Knows the difference between high and low months
    3. Knows the bill runs the same each month

40. Do you know the amounts of your gas and electric bills? Extra cost during colder or hotter months?
    0. Does not know or is very vague
    1. May know, but did not answer
    2. Knows amount of bill and differentials, probably sees price as both
    3. More emphasis on amounts than differentials
    4. More emphasis on marginal price

41. Do you know what is included in the bill?
    0. Does not know
    1. Knows whether bill includes a sewer or garbage charge

42. Has your water bill changed over the past five years?
    0. No change, or has changed by an insignificant amount.
    1. Increase has been substantial
    2. Not applicable (has only recently moved to the area, no basis for comparison, etc.)

43. Has your water bill changed as much as your other utility bills? (Indicate which of the following <u>best</u> reflects the customers understanding of <u>water</u> rates.)
    0. Understands (correctly) that the rate increase has been about the same as other prices in general, less than electric prices and more than gas prices.

1. Does not know what the relative changes have been (i.e., has no opinion).
2. Show considerable misunderstanding of relative prices.

44. If customer volunteers a comment on high electric rates, ask how much these rates have increased relative to other prices (i.e., encourage further comment). Record the response which best reflects customers belief.
    0. No comment or no definable position.
    1. Understands (correctly) that electric rates have increased up to 100%, other prices about 50%, and that rates are up about 25% in real terms. (i.e., has general understanding that the relative increase is less than the apparent change)
    2. Sees electric rates as doubling in absolute terms, no concept of relatives.
    3. Has no concept of how much but believes the increase has been unreasonably high.
    4. Other (briefly describe).

45. When your home was first constructed, was it well insulated with:
    1. Attic insulation
    2. Wall insulation
    3. Storm doors
    4. Storm windows
    5. All of the above
    6. 1 and 2
    7. 1 and 3
    8. 1 and 4

46. Has there been a regular effort to upgrade efficiency in your home since it was built?
    0. No
    1. Yes

    If so, what has been done?

47. What have you done in the last three (3) years to conserve energy in your home?

Card 2

48. What is the age of the head of household?

    _____

49. Where does the head of household work? What does he do?

    _____

    _____

(This information will serve only as a basis for estimating income or verifying the answer given. Record, as appropriate, from answer given:

0. Head is employed or (apparently) temporarily unemployed
1. Head is retired
2. Head is disabled or (apparently) generally unemployed (i.e., just does odd jobs, etc.)

50. Is the spouse employed outside the home? Where? What does spouse do?

_____

_____

_____

Record as appropriate

0. Spouse works at least part time most of the time
1. Has no outside employment

51. What was last year's family income from all sources?

___ ___ ___ ___ ___ ___ ___

In case respondent is reluctant to give precise level of income, use one of the intervals (A, B, or C) below. Take the mid-point or the chosen interval as the best estimates.

A

(1) $0-3,000
(2) $3,001-6,000
(3) $6,001-9,000

B

(4) $6,000-10,000
(5) $10,001-15,000
(6) $15,001-20,000

C

(7) $10,000-20,000
(8) $20,001-30,000
(9) $30,001-40,000
(0) over $40,000

52. Questionnaire validity as perceived by interviewer

1. Very reliable
2. Reliable

(continued)

3. Acceptable
4. Somewhat reliable
5. Very unreliable

53. Lot valuation

___ ___ ___ ___ ___

54. Total valuation

___ ___ ___ ___ ___

55. Frontage

___ ___ ___ ___ ___

56. Acreage

___ ___ ___

APPENDIX C

STATEWIDE SURVEY QUESTIONNAIRE

The questionnaire used in the general household survey was a part of a statewide energy use study. The questions given are those relating to water use. All rate structure and consumption data were collected from the water utility.

HOUSEHOLD QUESTIONNAIRE

I. Appliance Saturation:

1. Has dishwasher:
   - Yes
   - No

2. Has food waste disposer:
   - Yes
   - No

3. Type of clothes dryer:
   - Electric--combination washer-dryer
   - Electric
   - Natural gas
   - Bottled gas
   - None

4. Type of clothes washer:
   - Wringer
   - Automatic
   - None

5. Type of water heater:
   - Natural gas
   - Bottle gas
   - Electric
   - Other fuel
   - No water heater

   If ELECTRIC, what size water heater?
   - 30 gallon
   - 40 gallon
   - 50 gallon
   - 80 gallon
   - 120 gallon
   - Don't know

II. Demographic Data:

6. Type of residence:
   - Single family
   - Duplex
   - Apartment
   - Condominium
   - Mobile home

7. Type of tenure:
   Own residence
   Rent residence

8. Year moved into residence: _____

9. Year home built: _____Age of home: _____

10. County code: _____

11. Location of house:
    Metropolitan area
    Urban (Incorpcrated city limits)
    Suburb (Unincorporated area close to city)
    Rural-proximity of metropolitan area

    Nonmetropolitan area
    Urban (Incorporated city limits)
    Suburb (Unincorporated area close to city)
    Rural area

12. Type of neighborhood: (interviewer only)
    sub-standard area
    (section deteriorating) _____

    Declining neighborhood
    (changing to commercial) _____

    Older established area
    (age over 15 years - not declining) _____

    Newer residential area
    (age--5 to 15 years - developed) _____

    A new subdivision
    (in development stage, 5 years or less)_____

    Other: _____

13. Is home or apartment served by:
    Fire hydrants and/or full fire protection
    Garbage collection service
    Sewer service
    Water service
    None of these

14. Age of head of household _____

15. Total number of people living at this residence:_____

16. Number of children living at this residence:
    Preschool _____
    Elementary _____
    Junior high _____
    Senior high _____
    College _____
    (out of school - employed) _____
    (out of school - not working) _____
    None _____

17. Is head of household:
    Employed
    Not working
    Retired

    (a) If married, is spouse employed:
        Full-time outside employment
        Part-time outside employment
        Homemaker--no outside employment

    (b) If other adults, are they:
        Employed full-time
        Employed part-time
        Not working
        Retired

    (c) If employed,
        Where is head of household employed
        (name of employer):

        _____

        Type of employment:

        1. Title

           _____

        2. Duties

           _____

III. Dwelling Construction and Conservation

18. Number of square feet in home: _____

19. Have you reduced your energy use (gas or electric) of the following:

    Water heater Yes_____ No_____

    Dishwasher Yes_____ No_____

20. What is the 1976 Total Household Income (all sources) based on the following broad categories:

$6,000 or less
$6,001 to $10,000
$10,001 to $20,000
$20,001 to $30,000
$30,001 to $40,000
Over $40,000
Customer would not answer

Interviewer to complete Question

21. Mark the level of income based on your personal judgement:

Estimated Income category:
Low income - $6,000 or less
Lower middle income - $6,001 to $10,000
Middle income - $10,001 to $20,000
Upper middle income - $20,001 to $40,000
High income - Over $40,000